A Habitat Study of Created Wetland Sites in Delaware

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Introduction

In Delaware, approximately one quarter of the state is made up of wetlands. Over half of these wetlands have been lost since the early 1700s and are continued to be lost or converted to open water (Tiner, 2011). The state has also been projected to see a 7% increase of households from 2020 to 2050 (Delaware Population Consortium, 2019) increasing pressure for more infrastructure to support these growing population densities. This in turn has led to natural lands being sought after for their development potential. These natural lands have often included wetland features and have provided Delawareans benefits such as floodwater storage, water cleansing abilities, air purification, and wildlife habitat. The challenge that has been and continues to be, is the suitable way to find an equilibrium between the need for higher capacity roads, housing and agricultural lands while retaining natural landscapes that provide beneficial ecosystem services.

Wetland restoration or creation is a tool used by planners and land managers to offset impacts to other wetlands and/or improve the habitat and ecosystem services of an area. There are multiple methodologies available to restoration specialists to design wetland projects, whether they be voluntary or required mitigation projects, and include land alterations from filling in ditches, regrading land areas, to digging ponds or creating berms and planting tactic such as natural recruitment to planned landscaping. All these methods have been utilized to restore wetlands in Delaware, but the question remains if the wetlands created replaced what was lost?

In an attempt to offset these damages, reclaim some of the functions that wetlands provide, and comply with the policy of "no net loss of wetlands" (Natural Resources Conservation Service, 2011), a number of wetland restoration or creation and conservation programs have been developed over the years. These programs restore or protect wetlands through required mitigation efforts or voluntary easements.

On the national scale, wetland mitigation is governed through Section 404 of the Clean Water Act by the U.S. Army Corps of Engineers and allows for compensatory mitigation through three mechanisms: permittee-responsible, banking, and in-lieu fee (Department of Defense and Environmental Protection Agency, 2008). These types of mitigation are mandated and permitted by the government when wetland impacts are deemed unavoidable during the construction process.

- Permittee responsible mitigation is when the entity applying for the permit takes on the responsibility of performing and paying for the wetland restoration themselves.
- Mitigation banking works similar to a banking system where wetlands are assigned a value or credit and the permittee may purchase these credits from the "bank". The number of credits needed depends on the amount of impact that the development project will incur to wetlands.
- In-lieu fee mitigation refers to the process where the permittee directly pays a fee for someone else, usually a public or not for profit agency, to perform the wetland restoration (U.S. Environmental Protection Agency, 2008).

Alternatively, landowners have had the option to voluntarily restore, preserve, or enhance wetlands on agricultural lands through programs such as U.S. Department of Agriculture (USDA) Farm Service Agency's Conservation Reserve Program (CRP), Conservation Reserve Enhancement Program (CREP), and the Farmable Wetlands Program (FWP), or USDA's Natural Resource Conservation Service's (NRCS) Agricultural Conservation Easement Program (ACEP) or Wetlands Reserve Easement Program (WREP).

Each of these programs have contained varying term commitments and benefits to entice landowners to keep wetlands on their lands (USDA Farm Service Agency, 2006 & USDA Natural Resources Conservation Service, 2014).

Wetland creation, whether it be performed through mitigation or voluntary efforts, is an important tool for restoring vital wetland ecoservices to the communities of Delaware, yet little research has been produced by the state as to the effective-ness of wetland restoration in terms of reclaiming lost functions. There is also little research in Delaware that explores how to assess the condition and function of created sites (i.e., can we use or add to existing wetland rapid assessment methods, or do we need to create a new method). In 2009, the Delaware Department of Natural Resources' Wetland Monitoring and Assessment Program took a first step in evaluating the use of a rapid assessment method for created wetlands, and one of the recommendations that came from this study was to repeat the assessment in the years to come to see if changes in conditions specific to restored wetlands sites could be detected (Rogerson, 2010).

To provide insight into these notions and to improve wetland restoration practices in Delaware in the future, we seek to address four topics in this report:

1. How wetland acreage and type impacted compare to the wetland acreage and type created due to mitigation requirement during the construction of State of Delaware Route 1? DE Route 1 was chosen as a study site because it spans through a large portion of the middle of the State of Delaware. The construction of this highway impacted and caused a loss of a variety of wetland habitats, and because of this, wetland mitigation requirements were put in place.
2. Do created wetland projects implemented in the 1990s – early 2000s due to the construction of Delaware State Route 1 serve as a suitable replacement for wetland habitat and function lost?
3. What additional research or metrics are needed to utilize the Delaware Wetland Freshwater Rapid Assessment Method (DERAP) and/or Guidance for Rating Wetland Values in Delaware Protocol (Value Added) methods to rapidly evaluate wetland function of restored wetlands?
4. Can the individual restoration sites in this study be characterized as a wetland and insight into the performance and function of each site be garnered?

Synopsys:

As each of these questions were addressed a common theme became apparent: restored or created wetlands have not replicated the types of wetlands impacted or natural wetlands in Delaware. If or how this affects Delaware's flood water storage and water cleansing capabilities, or wildlife habitat at a landscape level remains unknown. The following pages account in detail the methodologies, data, and analyses as to how this conclusion was made.

Methods

GIS ANALYSIS: WETLANDS IMPACTED AND CREATED AS A RESULT OF THE CONSTRUCTION OF STATE OF DELAWARE ROUTE 1

Calculating Wetland Impacts Due to the Creation of Delaware Route 1

To assess the impact of the construction of Delaware Route 1 on Delaware wetlands, a GIS analysis was performed to calculate the acreage and types of wetlands that were impacted. Wetland impacts, wetlands that were destroyed or covered (a bridge for example), were estimated using ArcGIS ArcMap version 10.6.1 and the following layers: 1992 and 2007 State of Delaware wetland mapping; 1968, 1992, and 2007 years of aerial imagery; and DelDOT Transportation/DE_Centerline.

Delaware Route 1 construction started in 1991 in the northern extent of the project (the area where Delaware Route 1 intersected the historic U.S. Highway 13 south to the current north Smyrna Route 1 ramps). This allowed the use of the 1992 State of Delaware wetland mapping layer to assess the intersection of wetland polygons with the current location (2019) of Delaware Route 1, defined using the DelDOT Transportation/DE_Centerline layer. When overlap was determined, the location, Cowardin classification, and impacted wetland acreage were calculated using the measure tool and the 2007 wetland layer attribute table.

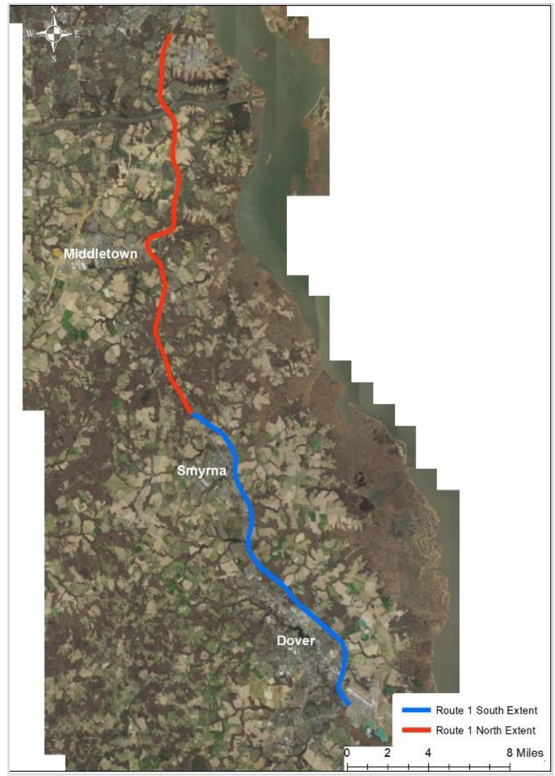

Figure 1 The northern extent (red), and the southern extent (blue) of the Delaware Route 1 study site.

A slightly different technique was used for the southern extent of the project (area below the current north Smyrna Route one ramps to the connection with historic U.S. Highway 13 at the Dover Air Force Base). Throughout this area the 1968 aerial imagery layer was included in addition to the aforementioned layers to calculate wetland loss. Construction had already begun on this stretch of Delaware Route 1 before the 1992 State of Delaware wetland layer and imagery were completed.

Data was compiled in an Excel spreadsheet with notes to explain each wetland loss occurrence.

Calculating Wetland Creation Due to Mitigation Requirements of Delaware Route 1

To assess the created wetlands designed due to the construction of Delaware Route 1 on Delaware's wetlands, an analysis was performed to calculate the acreage and types of wetlands that were created as a result of mitigation requirements. The Cowardin type (Cowardin, 1979) and acreage of created wetlands were determined using ArcGIS ArcMap with the State of Delaware 2007 and 2017 wetland maps; 1926, 1954, 1992, 1997, 2007, and 2017 aerial imagery; and the Mitigation_Sites_DelDOT boundary layer.

A list of wetland mitigation sites that were created as a result of the construction of Delaware Route 1 was obtained from the Delaware Department of Transportation (DelDOT) staff and included the following: Booker, David, Eisenbrey, Fusco, Hall, Hurd, Island Carey, Lynch (ABC), Norvell, Osborne, PNC, Pollack, Puncheon Run, Royter, Roberts, and Sarro. The construction of Delaware Route 1 began in 1992 while these wetland mitigation projects were constructed from 1995 to 2002.

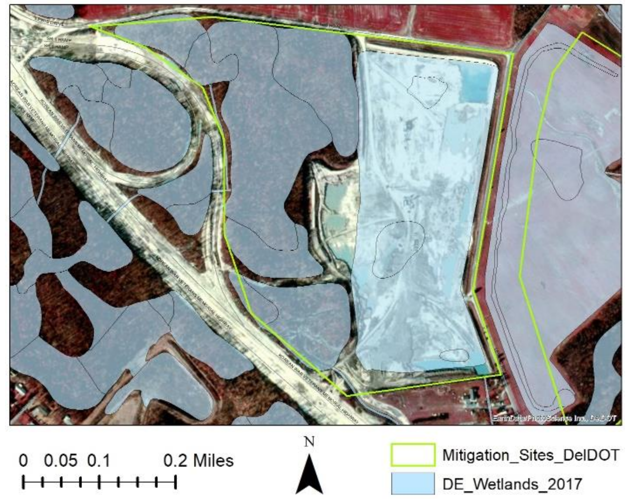

Figure 2 Pictured here is an example of a mitigation site that contained natural and restored wetlands. Differentiation of wetland categories were determined in this instance using 1992 aerial imagery and 2017 wetland maps. Note the disturbed verses forested areas.

Using ArcMap, the boundary of each mitigation site was determined by using the Mitigation_Site_DelDot layer, and the location, Cowardin classification, and created wetland acreage were determined using the 2017 State of Delaware wetland maps. If inaccuracies existed for the 2017 mapped wetland extent, the wetland acreage was determined by using the measure tool and referencing 2017 aerial imagery. Only created wetlands were recognized in this analysis. If, in looking at historic aerial imagery, it was determined that the wetland was natural or not created as a result of Delaware Route 1, it was not included in the acreage calculations (Figure 2).

Data was compiled in an Excel spreadsheet with notes to explain wetland type or features of interest. Data on site expectations for Eisenbrey, Fusco, Lynch A,B,C, Osborne, Norvell, PNC, and Puncheon Run, was determined from the Delaware Department of Transportation SR1 Phase II Wetland Mitigation Sites 2013 (Year 10) Monitoring report (Century Engineering, 2014).

FIELD PROJECT: ASSESSING DELDOT WETLAND MITIGATION AND PRIVATE WETLAND RESTORATION SITES

Selecting Sites and Acquiring Site Access (2018-2019)

Sites selected for this project were either Delaware Department of Transportation (DelDOT) wetland mitigation projects, Delaware Department of Natural Resource and Environmental Control (DNREC) wetland restorations or USDA's Natural Resource Conservation Service (NRCS) sponsored landowner wetland restoration projects visited in 2018 or 2019. The wetland mitigation projects were designed and contracted out by DelDOT on DelDOT property to offset the removal of wetlands when the State of Delaware Route 1 corridor was built in the early 1990s. The DNREC wetland restoration project was on DNREC property, and was designed and constructed through DNREC. The NRCS wetland restoration projects were on private land where landowners voluntarily expressed interest in restoring wetlands on their own property, and restorations were designed and contracted out through NRCS. Access to sites sampled was granted through these agencies.

The wetland restoration sites selected for this study were freshwater non-tidal, on public and private land, and were selected because they were either a previous Delaware Rapid Assessment Procedure for Freshwater Wetlands (DERAP) study performed by the Delaware Department of Natural Resources

(DNREC) Wetland Monitoring and Assessment Program (WMAP) in 2009, or were selected as a new site of interest. A total of 14 projects, 17 assessment areas spanning the creation years of 1995 to 2002 were sampled.

Reference sites were obtained by using data from WMAP's wetland health assessments. Wetlands categorized as depressions or flats on public lands with a Qualitative Disturbance Rating (DERAP, 2010) of 1 in the Smyrna or St. Jones River Watersheds were considered reference condition for this study. A total of 5 reference sites were sampled for this project.

Using the DERAP/Value Added Wetland Assessment Methods

In 2018/ 2019, each site was sampled using the Delaware Rapid Assessment Procedure (DERAP, 2010), and the Value Added Method (DERAP Value, 2014) for freshwater wetlands and given a wetland type of depression or flat based on site characteristics. DERAP and the Value Added Method are intended to be used in natural freshwater wetlands, not created sites. Therefore, in performing methods, all wetlands were assumed to be natural. Any disturbance that happened in the wetland before its creation was ignored, and no Qualitative Disturbance Rating was given.

The Delaware Rapid Assessment Procedure (DERAP) and Value Added method for freshwater wetlands were used to collect data on the health of created verses reference condition wetlands (DERAP, 2010, and DERAP Value 2014). These methods have been historically used to capture the health of natural wetlands within the State of Delaware, and thus a useful starting point for assessing created or restored wetland health. For this field study, 17 created wetlands and 5 reference wetlands were assessed, and each assigned an hydrogeomorphic (HGM) category of either depression or flat using the field crew's best professional judgement. This was sometimes difficult in restored wetlands due to the unnatural morphology of the created sites.

Establishing the Assessment Area

At each wetland restoration site an assessment area (AA) was established. The AA was configured to be a 0.5 ha circle around a pre-determined center point (40m radius). If the wetland sampled was smaller than 0.5 ha, the shape was reconfigured to fit the size and shape of the wetland. Transects were laid out in a plus sign for circular AAs or fitted for a rectangular shape with each transect following cardinal direction (N, S, E & W). Eight $1m^2$ plots were established along each transect in the 2018/ 2019 assessment years (Figure 3).

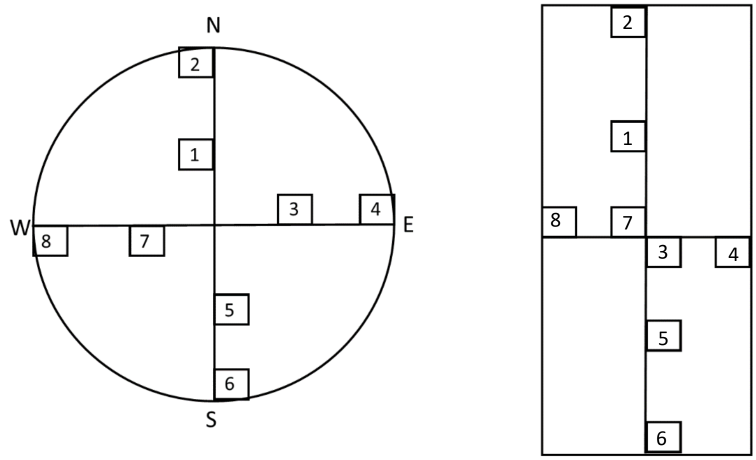

Figure 3 Layouts for transects (lines) and 1m^2 plots (small rectangles) for circular (left) and rectangular (right) shaped assessment areas.

If the restoration site was previously sampled in the 2009 DERAP study, the same center point or assessment area was used. The 2009 DERAP study was performed as an initial effort to collect data on the use of DERAP for created wetlands, and the study coincided with the assessment of natural wetlands in the St. Jones River watershed. One recommendation from this report was to perform a repeat assessment in the future to garner an understanding for timelines for wetland restorations (Rogerson, 2010), and was the reasons this dataset was chosen for this project.

For newly sampled sites (2018-2019), a center point(s) was located in a representative wetland type of the site. Due to the size of the created wetland or the presence of multiple wetland types, some wetland restoration sites contained multiple AAs to ensure a representative sample of the wetland.

Assessing Plant Communities

Plant communities were assessed within each AA. Photos were taken at center in all four cardinal directions. A list of all plant species was written down as the site was traversed. Photos and percent cover of plant species in a 1m^2 plot of all strata was recorded at plots 1, 3, 5, and 7. Dominant plant types of plots were denoted if they reached ≥55% in plots. If a plant could not be identified in the field, photos were taken and identified back in the office.

Horizontal vegetative obstruction, which visually quantifies the thickness of plants at 0.25m intervals from the ground up to 1.25m (Delaware Department of Natural Resources and Environmental Control, 2017), was performed at each site in plots 1, 3, 5 and 7. Plant height class of plants greater than 10% coverage of the AA was recorded, classes include: floating/aquatic, short (<0.5m), medium (1.5m-3.0m), tall (1.5m-3.0m), and very tall (3.0m) (California Wetland Monitoring Workgroup, 2013).

Understanding Soil Properties

Wetland restoration sites were created using heavy machinery, a practice which has been known to cause soil compaction. Two different soil compaction assessment methods were used to understand if one method would be preferential in a rapid assessment of soil properties. Soil bearing capacity was performed and measured the stability of the ground surface (Delaware Department of Natural

Resources and Environmental Control, 2017). It was performed at all 8 plots. A penetrometer was used at plots 1, 3, 5 and 7 using a ½” tip to measure soil compaction. The device was inserted in the soil with even pressure and measurements recorded every 3”, stopping when the device would not go any deeper.

A soil profile was taken as close to the center point as possible at each AA using an auger or shovel; Matrix and redox feature colors were determined at 5cm and 20cm depths (Munsell Color, 2012), depth of organic layer, and depth of groundwater, if any, were recorded. If the center point contained too much water, an alternate location in the AA with similar features was sampled.

RESULTS: A GIS Review of Wetland Acreage and Type Impacted and Created During the Construction of Delaware State Route 1

Wetland mitigation is a practice that is used to offset unavoidable impacts to wetlands that occur during construction projects and is an effort to strike a balance between development needs and the retainment of natural resources. But how effective is this process in replacing or making up for the wetlands that have been impacted? *This part of the project aimed to provide insight into the questions: did wetlands created as a result of Delaware Route 1 construction impacts replace the wetland types lost, and what implications could these changes, if any, mean for their effectiveness in performing wetland benefits that's Delawareans depend on.*

Replacing Impacted Wetlands

As displayed in Figure 4, the analysis revealed that as of the 2017 State of Delaware wetland mapping effort the total acreage of wetlands created (317.36 acres) was 43% more than the acreage of wetlands impacted by the construction of Delaware Route 1 (205.9 acres).

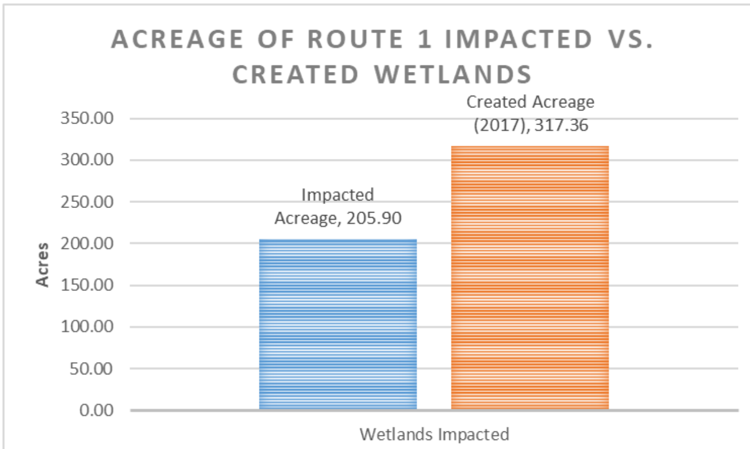

Figure 4 Acreage of wetlands impacted by Delaware Route 1 construction and wetlands created as a result of mitigation requirements.

However, the types of wetlands created, tabulated by Cowardin classification, do not align with the types of wetlands that were impacted. Based off of the GIS analysis, gains were seen in palustrine unconsolidated bottom (PUB), palustrine emergent (PEM), and palustrine emergent/ scrub shrub (PEM/SS) wetland categories, while losses of palustrine scrub shrub/ emergent (PSS/EM), palustrine forested (PFO) and estuarine (E) wetland categories were seen. The palustrine forested (PFO) wetland category suffered the greatest losses (Figure 5).

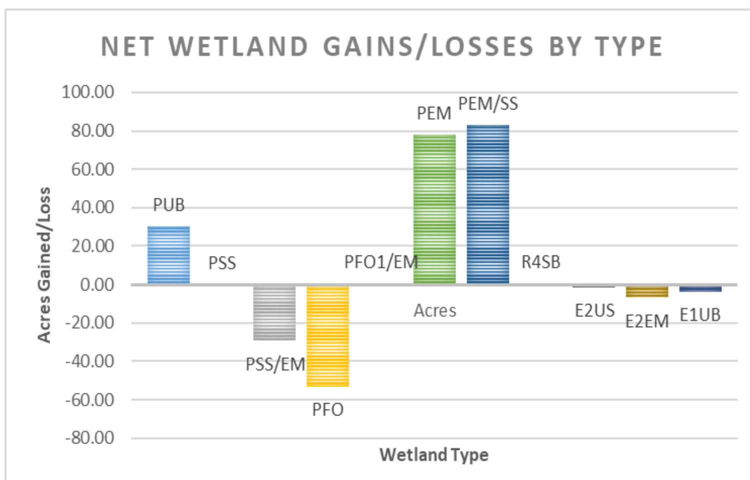

Figure 5 Gains and losses of wetland impacts, by Cowardin classification, due to the creation of Delaware Route 1 and the resulting wetland mitigation requirements.

This discrepancy also followed through for the Eisenbrey, Fusco, Lynch ABC, Osborne, Norvell, PNC and Puncheon Run wetland mitigation sites when the intended created wetland type (Century Engineering, 2014) was compared with the classification mapped in State of Delaware's 2017 wetland mapping effort (Table 1). Overall, these wetland mitigation sites appeared to be trending towards palustrine emergent (PEM) or palustrine unconsolidated bottom (PUB) wetland types rather than palustrine forested (PFO) or palustrine scrub shrub (PSS) wetlands. The PNC site was the only site field verified as a PEM wetland and did correspond to the type designated by the 2017 wetland maps.

Differences in the Cowardin water regime modifiers between wetlands impacted verses created were also determined, as the created mitigation wetlands were mapped wetter. The 1992 impacted wetlands water regimes were predominantly As, Bs and Cs (temporarily flooded, saturated, and seasonally flooded), and the 2017 wetland mitigation sites were predominately Es, Fs and Hs (seasonally flooded/saturated, semi permanently flooded, and permanently flooded) (Figure 6 and 7).

Furthermore, forested wetlands (PFO) were highlighted as the most vulnerable to loss and a shift towards palustrine unconsolidated bottom wetlands (PUB) were documented in the 1992 and 2007 Delaware Wetlands Status and Trends reports. These changes predominately came from the agriculture sector, transitional lands, or residential development and reinforce the need to explore the efficiency of created wetland types to perform ecosystem services (Tiner, 2001 & 2011).

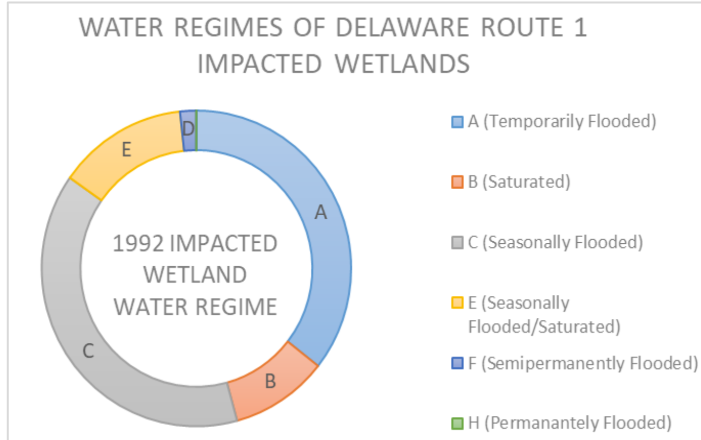

Figure 6 Breakdown of water regimes, determined from 1992 Delaware wetland mapping Cowardin classification, of wetlands pre-impact during the Delaware Route 1 construction.

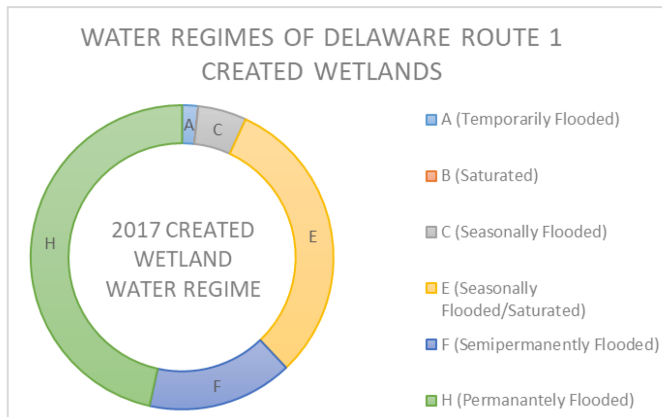

Figure 7 Breakdown of water regimes, determined from 2017 Delaware wetland mapping Cowardin classification, of wetlands created as mitigation requirements of Delaware Route 1.

Table 1 This table shows the intended created wetland type using the Cowardin classification (Century Engineering, 2014) and the actual created acreage as determined by the 2017 State of Delaware wetland maps. Information was only available for a select number of sites, and acreage for enhanced or preserved wetlands was not considered.

DelDot Mitigation Site Name	Intended		2017 Mapped Actual	
	Classification (Cowardin)	Acres	Classification (Cowardin)	Acres
Eisenbrey	E	0.60	E	1.38
	Total Acres	*0.60*	*Total Acres*	*1.38*
Fusco	E	1.80	PUBTx	1.56
	Total Acres	*1.80*	*Total Acres*	*1.56*
Lynch A,B,C	PFO	27.90	PFO	1.37
	PEM/SS	3.60	PUB	2.67
			PSS/EM	4.77
			PSS	0.14
			PEM	0.09
	Total Acres	31.50	*Total Acres*	9.05
Osborne	PFO	93.66	PEM	13.50
			PUB	14.39
	Total Acres	*93.66*	*Total Acres*	*27.89*
Norvell	PFO	0.98	PEM	1.32
	PEM/SS	0.95		
	Total Acres	1.93	*Total Acres*	*1.32*
PNC	PEM/SS	3.93	PEM	11.41
	PFO	12.27	PUB	4.52
	Total Acres	*16.20*	*Total Acres*	*15.93*
Puncheon Run	PEMT	0.30	PUB	0.59
	PEM/SS	0.87	PEM	1.69
	PFO	0.57	PFO/EM	0.60
	Total Acres	*1.74*	*Total Acres*	*2.87*

Differences in Ecosystem Services

Research has suggested that wetland restoration sites do not perform at the same level as natural wetlands (Gebo, 2012), but data about the nuances in the functional performance of different wetland types related to vegetation and water regimes seemed to be lacking. This study demonstrated a trend towards palustrine emergent (PEM) or palustrine unconsolidated bottom (PUB) wetlands over palustrine forested (PFO) or palustrine scrub shrub (PSS) wetlands within Delaware's created wetland mitigation sites. To that end, did this shift increase or decrease the lands ability to absorb nutrients, sequester carbon, or control flood waters? In this section our analysis was combined with a quick literature review to seek out possible implications in the reduction of forested or scrub shrub wetlands and increase in emergent and unconsolidated bottom wetlands. Across the multiple papers reviewed, the following factors were noted as important features for a wetland to effectively remove nutrients: woody versus herbaceous plant species composition, the connectivity to water sources, and the wetland's location on the landscape.

The presence of native plants has long been known as a factor to discern wetland health and provide benefits such as habitat and water quality. More specifically, forested wetlands have been found to use and sequester more nutrients than emergent wetlands. Lane et al. (2015) determined that forested wetlands have higher organic content than emergent marshes which has allowed them to uptake and sequester large amounts of phosphorus, although their effectiveness in doing so depended on the wetland's disconnection from water features. The National Wetland Condition Assessment by the U.S. Environmental Protection Agency (2016) found that wetlands "dominated by woody rather than herbaceous vegetation consistently had lower total nitrogen, total phosphorus, and chlorophyll," which has implications for more efficient nutrient uptake for forested and scrub shrub wetlands. Also, a literature review by Fisher et al. (2004) concluded that each wetland type performed different functions to varying degrees (i.e. the amount of uptake of phosphorus or nitrogen changed depending on the wetland type). If a wetland was needed to reduce phosphorus, it should have been designed to have dry areas or seasons, whereas if nitrogen reduction was the primary target, then wetter environments should have been created to allow for the proper chemical reactions to occur.

In addition to vegetation type, another important factor for wetland nutrient uptake was the supply, amount, and connectivity or lack-thereof to water. The amount and seasonality of water in a wetland dictated what species of plants can germinate and grow, what wildlife uses the habitat, the capacity to prevent downstream flooding, and the ability to retain nutrients. Ensuring wetlands have seasonal variations in their hydroperiods ensured that the wetland functioned efficiently, and a wetter wetland was not necessarily better (Jarzemsky, 2013). Unconsolidated bottom wetlands or ponds can hold large volumes of water but were usually stagnant and are not hospitable environments for most wetland vegetation to grow. The features in this type of habitat allowed nutrients to be contained in the water body but did not necessarily allow for the removal of said nutrients, so when storm events occurred and the pond overflowed, the likelihood of nutrient transportation out of the ponded system was high. Alternatively, forested, scrub shrub or emergent wetlands supported an environment for trapping and encapsulating suspended sediments and nutrients due to their seasonal variations of water levels which wetland plants prefer (Wong, 1999).

Conclusion

On a landscape level, more wetlands were created than impacted as a result of the Delaware Route 1 construction. What became evident during this process was that in the future, the goal or need of a created wetland project should be considered first and foremost and followed through when the wetland is designed. This is not a novel idea, but one that needs emphasis since research has demonstrated that plant type and water regime play an important role in a wetland's ability to perform ecosystem services, and that the wetland types created as a result of Delaware Route 1 construction were not necessarily of the types and water regimes impacted.

Woody wetland types such as forested and scrub shrub wetlands can process phosphorus more efficiently, and considerations should be made to ensure the survival of this type of vegetation in projects. Variable hydroperiods that create wet, anoxic conditions are important for the processing of nitrogen, but wetlands that are stagnant and ponded year-round might not be able to function the most efficiently. While ponded wetlands have the capacity to store large volumes of water, they do not necessarily have the ability to process large volumes of water. Nutrient sequestration and suspended sediment capture are best performed with variations in hydroperiods which then allows for diverse vegetation.

It may be helpful for research to further explore the possible process variations in natural wetland types, and not just restored or natural wetlands, to gain a better understanding of what exactly is happening within watersheds. This would be especially important in areas, such as Delaware, where a multitude of wetland types exist across the Coastal Plain and Piedmont regions. Steven et al, (2011) even suggested that creating "standards referencing the wetland type restored or the habitat-management technique used would bring wetland practices more into line with practice suites that have defined subclasses, such as conservation buffers."

In looking to a future of sustainable growth for Delaware, an understanding of land management practices that strike a balance between form and function will be critical to sustaining the ecosystem services that natural wetlands provide.

RESULTS: A Field Study of Created Verses Natural Wetland Sites

The GIS analysis of Delaware Route 1 wetland impacts described earlier in this report found that there were less impacted wetland acres than restored wetland acres, but the wetland types created did not match those impacted in type or water regime. From a mapping point of view, they appeared to be wetter and less woody. Furthermore, a literature review determined that woody plant community and water abundance influenced the performance of a wetland to improve water quality.

To investigate if differences in wetland health and features in sites created could be seen, a field study was conducted of a select number of DelDOT created wetland mitigation sites, a DNREC restoration wetland site, and USDA's Natural Resource Conservation Service's (NRCS) voluntary wetland restoration program sites.

Data

Overall, created wetlands ranked in the moderately to severely stressed DERAP categories, and the limited to moderate value category for the Value Added method. Reference wetlands ranked in the minimally to moderately stressed DERAP categories and rich to moderate value categories for the Value Added method (Figures 8,9 & 10).

The DERAP and Value Added assessment methods were created to be a rapid assessment of a wetland, in an effort to gain more detailed insight on specific wetland features including vegetation composition, hydrology, and soils additional metrics were supplemented as described in the methods section.

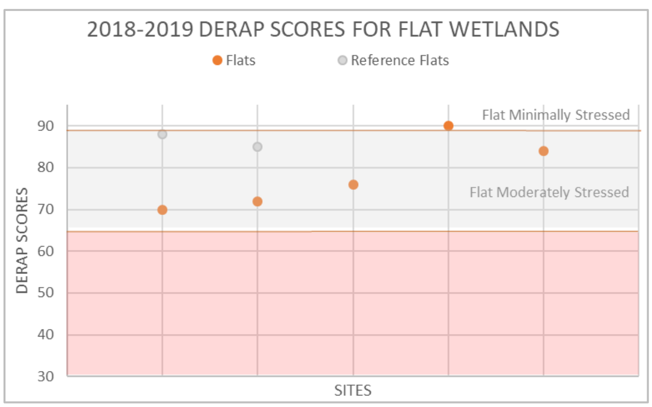

Figure 8 DERAP scores for flat reference and restored wetlands assessments in the 2018-2019 years.

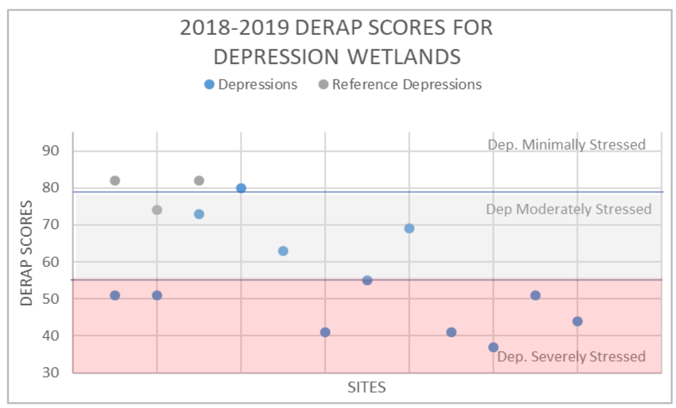

Figure 9 DERAP scores for depression reference and restored wetlands assessed in the 2018-2019 years.

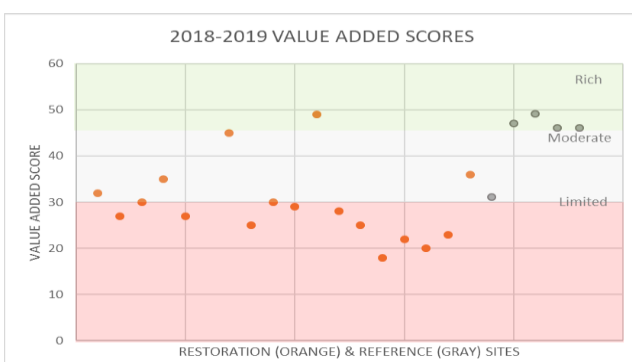

Figure 10 Value Added scores for depression and flat reference and restored wetlands assessments in the 2018-2019 years.

Vegetation

Vegetation in wetlands plays an important role in stabilizing and trapping sediments, slowing down water flows and absorbing nutrients, but how efficiently these processes occur depends on the plant communities present. To determine if plant species composition was different between created and reference sites, the existence of plant species were recorded in plots of assessment areas and then categorized into the following: standing water/ bare ground, aquatic, nonvascular, herbaceous, or woody vegetation (Table 2). The vegetation plot findings indicated that these created wetlands contained more herbaceous plants and standing water or bare ground than the reference wetlands, while nonvascular species representation remained similar across both created and reference wetlands, and aquatic species did not have representation in the reference wetlands. The reference and created wetland vegetation figures pools data from both flats and depressions (Figure 11 & 12).

Plant composition of the created wetland sites was found to be more diverse, primarily within the herbaceous category, than the reference wetland sites. In created assessment areas, common species of herbaceous plants were rushes (*Juncus* spp.), marsh seedbox (*Ludwigia palustris*), smartweeds (*Persicaria* spp.), and European reed (*Phragmites australis* subspp. *australis*) and common species of woody plants were red maple (*Acer rubrum*) and sweet gum (*Liquidambar styraciflua*). In reference assessment areas, common species of herbaceous plants were partridgeberry (*Mitchella ripens*) and sedges (*Carex* spp.), and common species of woody plants were sweet pepperbush (*Clethra alnifolia*), red maple (*Acer rubrum*), highbush blueberry (*Vaccinium corymbosum*), and sweet gum (*Liquidambar styraciflua*) (Table 2).

Invasive species were found primarily in the created wetland assessment areas (Figure 13 and 14). The common species found in individual assessment plots were European reed (*Phragmites australis* subspp. *australis*), Japanese honeysuckle (*Lonicera japonica*), alien bulrush (*Schoenoplectus mucronata*), barnyard grass (*Echinochloa crus-galli*), narrowleaf cattail (*Typha angustifolia*), and multiflora rose (*Rosa multiflora*) (Table 2). This outcome was not unexpected as invasive plant species commonly take hold in areas that have been heavily disturbed or in transition, such as those of created wetlands.

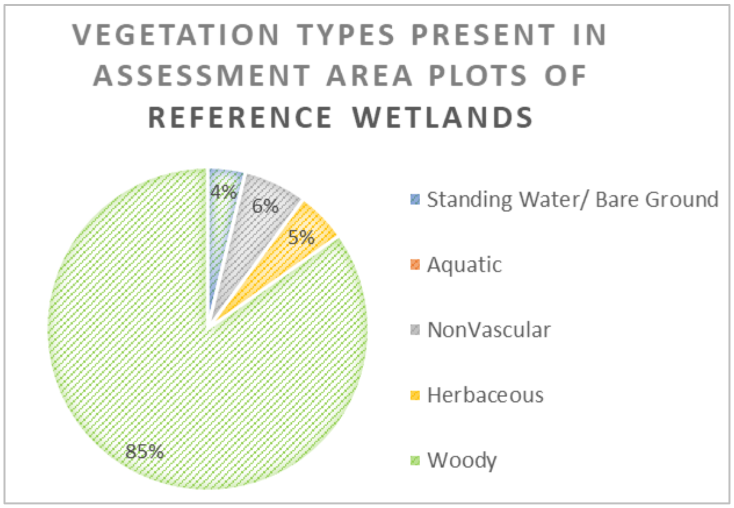

Figure 14 Percentage of vegetation categories present in plots of reference wetland assessment areas.

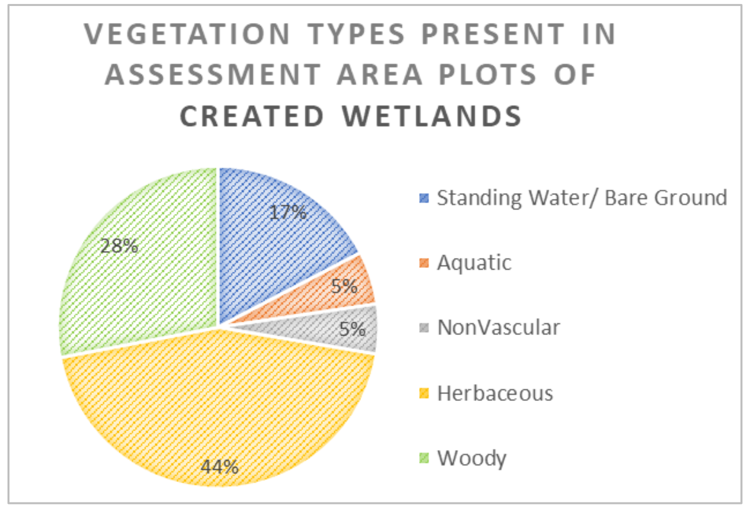

Figure 12 Percentage of vegetation categories present in plots of created wetland assessment areas.

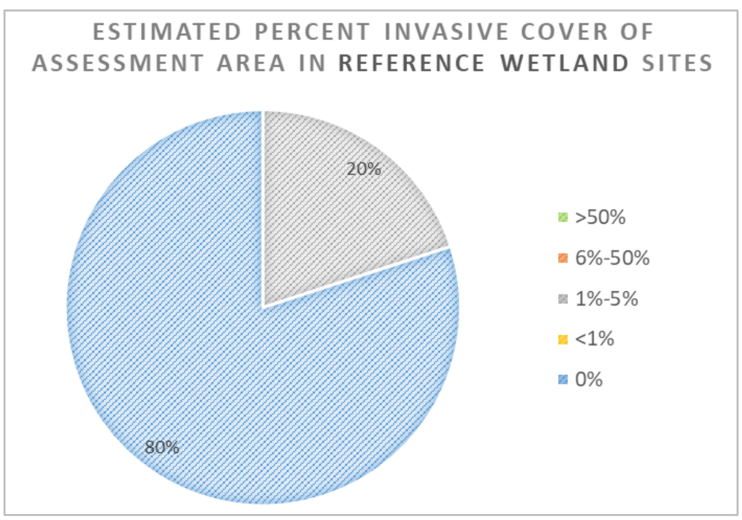

Figure 13 Percentage buckets of invasive cover of restored wetland assessment areas from DERAP assessment method.

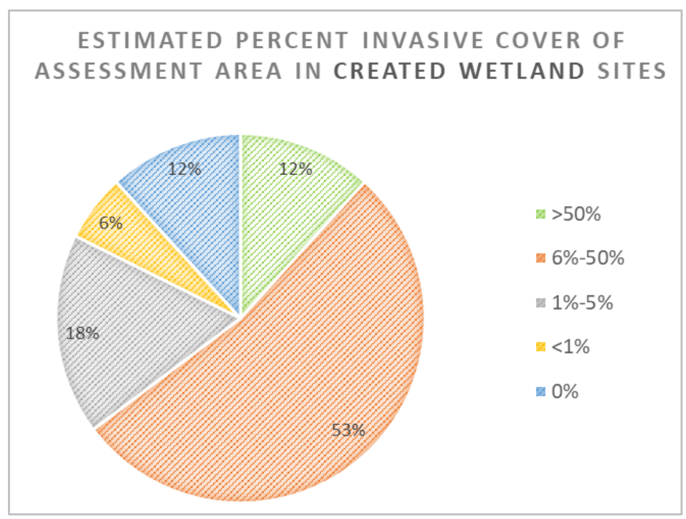

Figure 11 Percentage buckets of invasive cover of created wetland assessment areas from DERAP assessment method.

Table 2 Plant species present in assessment area plots of created and reference wetlands. Data represents the count of plots the species was present in, and species "" or highlighted in red are invasive.*

Wetland Restoration/Mitigation Sites (60 Plots)			Freshwater Wetland Reference Sites (20 Plots)		
Plant Species		Occurrence in Plots	Plant Species		Occurrence in Plots
Standing Water/Bare Ground		48	Standing Water/Bare Ground		3
Aquatic	Duckweed (*Lemnoideae* spp.)	14	NonVascular	Moss (*Sphagnum* spp.)	5
NonVascular	Moss (*Sphagnum* spp.)	11	Herbaceous	Partridgeberry (*Mitchella ripens*)	2
	Algae	2		Sedges (*Carex* spp.)	1
Herbaceous	Rushes (*Juncus* spp.)	16		Royal Fern (*Osmunda regalis*)	1
	Common Reed (*Phramites australis* subspp. *australis*)*	14	Woody	Sweet Pepperbush (*Clethra alnifolia*)	13
	Marsh Seedbox (*Ludwigia palustris*)	13		Red Maple (*Acer rubrum*)	10
	Smartweeds (*Persicaria* spp.)	13		Highbush Blueberry (*Vaccinium corymbosum*)	8
	Sedges (*Carex* spp.)	8		Sweet Gum (*Liquidambar styraciflua*)	8
	Beggarticks (*Bidens* spp.)	7		Black Gum (*Nyssa sylvatica*)	7
	Rice cutgrass (*Leersia oryzoides*)	7		Roundlief-Greenbriar (*Smilax rotundifolia*)	6
	Goldenrod (*Solidago* spp.)	6		Swamp White Oak (*Quercus bicolor*)	4
	Climbing Hempweed (*Mikandia scandens*)	4		Sassafras (*Sassafras albidium*)	2
	Spikerush (*Eleocharis* spp.)	4		American Holly (Ilex opaca)	1
	Woolgrass Bulrush (*Scirpus cyperinus*)	4		Black Huckleberry (*Gaylussacia baccata*)	1
	Deer Tongue Witchgrass (*Dichanthelium clandestinium*)	3		Fetterbush (*Eubotrys racemosa*)	1
	False Nettle (*Boehmeria cylindrica*)	3		Ironwood (*Ostreya* spp.)	1
	Fireweed (*Erechtites hieraciifolius*)	3		Northern Red Oak (*Quercus rubra*)	1
	Milkweed (*Asclepias* spp.)	3		Pin Oak (*Quercus palustris*)	1
	Alien Bulrush (*Schoenoplectus mucronata*)*	2		Swamp Chestnut Oak (*Quercus michauxii*)	1
	American Water Plantain (*Alisma subcordatum*)	2		White Oak (Quercus alba)	1
	Mock Bishopweed (*Ptilimnium capillaceum*)	2		Willow Oak (*Quercus phellos*)	1
	Rose Mallow (*Hibiscus moscheutos*)	2			
	Trumpet Vine (*Campsis radicans*)	2			
	Barnyard Grass (*Echinochloa crusgalli*)*	1			
	Broadleaf Arrowhead (*Sagittaria latifolia*)	1			
	Bugleweed (*Lycopus* spp.)	1			
	Fern spp.	1			
	Flatsedges (*Cyperus* spp.)	1			
	Narrowleaf Cattail (*Typha angustifolia*)*	1			
	Perfoliate Thouroughwort (*Eupatorium perfoliatum*)	1			
	Pickerelweed (*Pontederia cordata*)	1			
	Swamp Dock (*Rumex verticillatus*)	1			
	Violet (*Violet* spp.)	1			
Woody	Red Maple (*Acer rubrum*)	21			
	Sweet Gum (*Liquidambar styraciflua*)	14			
	Bald Cypress (*Taxodium distichum*)	7			
	Virginia Creeper (*Parthenocissus quinquefolia*)	4			
	Black Willow (*Salix negra*)	3			
	Hickory (*Carya* spp.)	3			
	Japanese Honeysuckle (Lonicera japonica)*	3			
	Poison Ivy (*Toxicodendron radicans*)	3			
	Swamp Chestnut Oak (*Quercus michauxii*)	3			
	Water Oak (*Quercus nigra*)	3			
	Willow Oak (*Quercus phellos*)	3			
	Rubus spp.	2			
	Southern Bayberry (*Morella cerifera*)	2			
	Ash (*Fraxinus* spp.)	1			
	Black Gum (*Nyssa sylvatica*)	1			
	Crabapple (*Malus* spp.)	1			
	Multiflora Rose (*Rosa multiflora*)*	1			
	Persimmon (*Diospyros virginiana*)	1			
	Pin Oak (*Quercus palustris*)	1			
	River Birch (*Betula nigra*)	1			
	Sycamore (*Platanus occidentalis*)	1			

Hydrology

Wetland hydrology is important for creating habitats that have appropriate water supplies to support desired wetland vegetation and function. To assess water levels of created and reference wetland sites, data was collected for the average water depth across the assessment area and estimates on the percentage of the assessment area flooded. The mean average water depth across created wetland assessment areas was 12.39 ± 13.59 cm while the mean average for reference wetland assessment areas was 3.74 ± 3.27cm. Both created and reference wetland sites had assessment areas that contained no water. The largest average water depth for created wetlands was 37.38 ± 14.55 cm while the largest average water depth for the reference wetlands was 7.5 ± 10.92 cm (Figure 15). Taking into consideration that the time of these field visits was late summer, the dry time of the year, one might expect water depths to be on the shallow end.

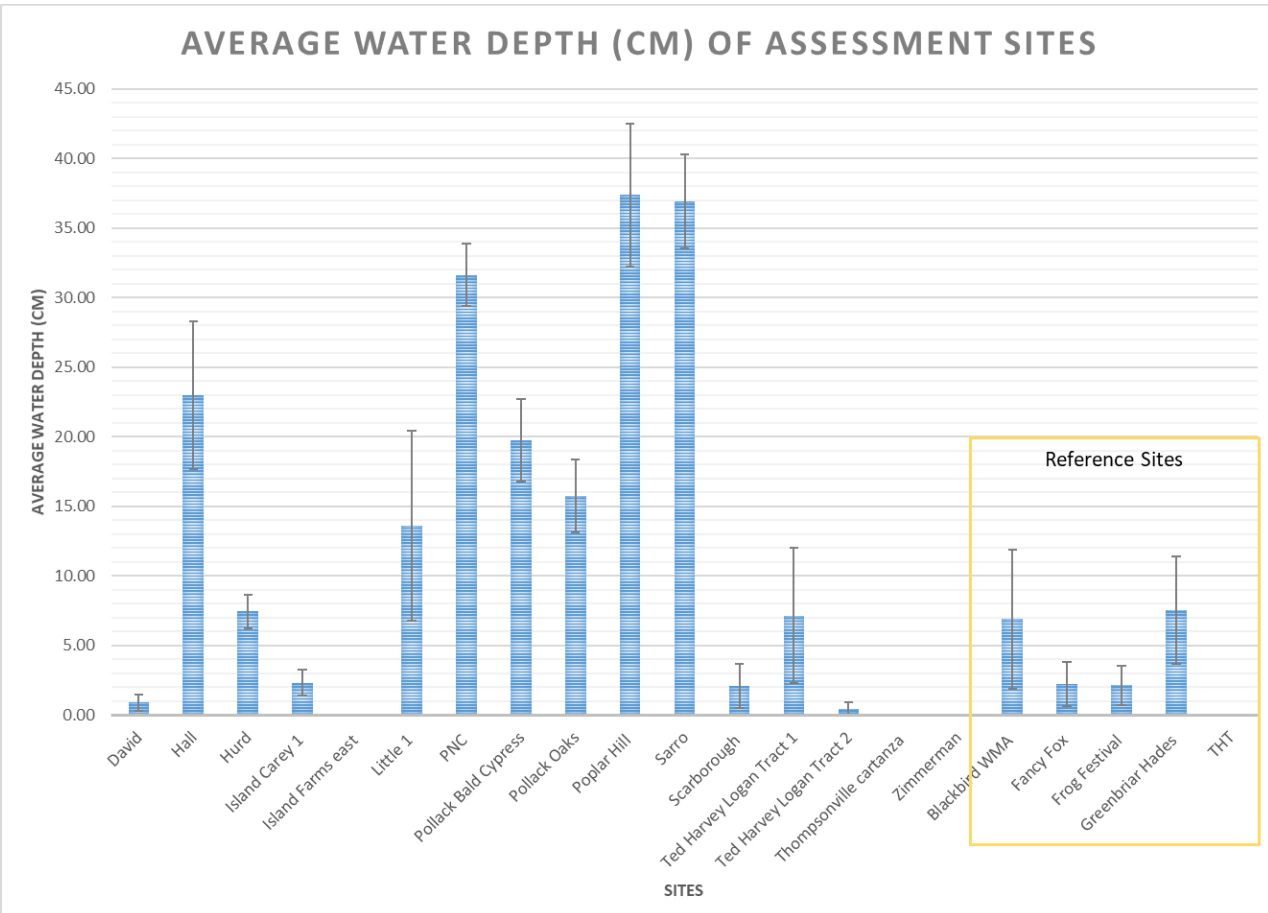

Figure 15 Average water depth (cm) with standard error of mean of created and reference (outlined in yellow box) wetlands during the late summer.

In created wetland sites, the majority of assessment areas had greater than 75% coverage of water over the surface, while the majority of reference wetlands had between 50% to 75% coverage of surface water (Figure 16 & 17).

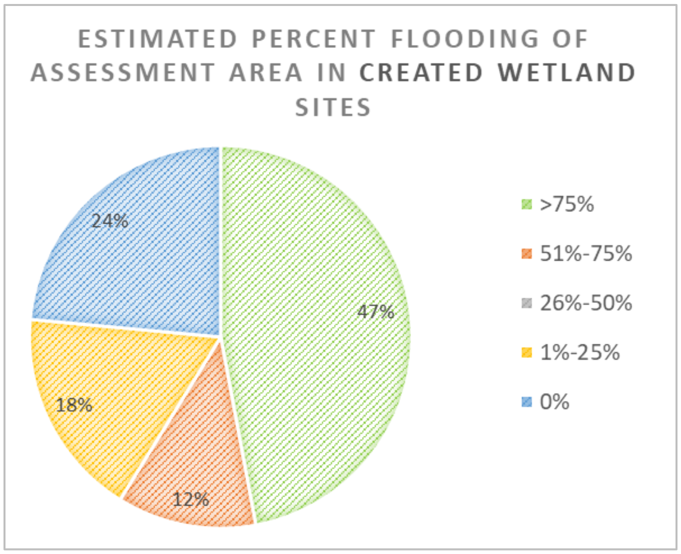

Figure 17 Coverage of water over the surface of the created wetlands. Measurements were recorded in percent coverage buckets.

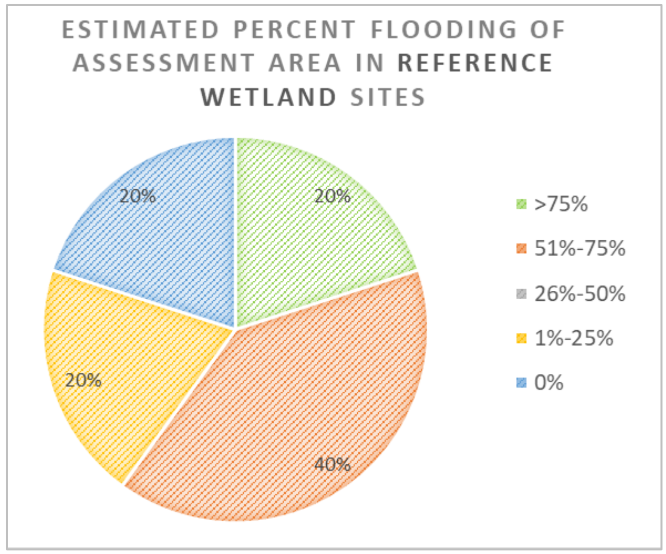

Figure 16 Coverage of water over the surface of the reference wetlands. Measurements were recorded in percent coverage buckets.

Soils

Table 3 Average pounds per square inch (PSI) penetration depths in created verses reference wetlands.

Pounds Per Square Inch (PSI) of Soil Depth				
Depth (in)	**Created Wetlands**	**Standard Deviation**	**Reference Wetland**	**Standard Deviation**
3	83	84	66	50
6	140	111	113	82
9	160	102	164	84
12	193	95	201	93
15	197	102	212	68
18	204	100	233	74
21	227	99	224	93
24	214	119	218	69
27	215	108	252	72

Hydric soils are created due to the lack of oxygen that watery environments provide and allow for the creation of a unique type of habitat. The time it takes for non-hydric soils to become hydric is a topic of interest in the scientific community. Within this study, we were not able to find significant differences in the soil's matrix and redox colors, bearing capacity, or penetrometer readings of created and restored wetland sites. The penetrometer data did show some small differences within the first 6 inches of the soil depth, but more data would need to be collected to properly discern differences (Table 3).

Conclusion

Created wetlands assessed in this study ranged from 15 to 22 years old at the time of the 2018-2019 field work and were significantly different in their plant communities and water regimes from natural wetland habitats in Delaware. Vegetation communities were more diverse and had a larger herbaceous plant composition in created wetlands, yet invasive species were also a common problem. Created sites also had more coverage and depth of water than reference sites which leaves questions about the future of the wetland sites and whether they will turn to open ponds due to heavy inundation and plant drownings.

These findings were not dissimilar to other research where it was found that created wetlands contained diverse plant assemblages that were different than natural wetlands and did not have features that mimicked natural wetlands (Yepsen, 2014 and Campbell, 2002). In speaking with DelDOT, it was our understanding that the majority of the created wetland sites were designed to be very wet and not necessarily to replace the types of wetlands impacted. Yet, this leaves us questioning if this design method leaves room for unintended consequences that impact the overall health of Delaware's ecosystems?

While this study cannot answer the aforementioned big picture question, it did determine that individual restored wetlands scored moderately to severely stressed with DERAP. This is somewhat misleading since DERAP was designed to assess natural wetlands and created wetlands are inherently different, but it should raise questions as to the effectiveness of past wetland design practices.

A Look into Using the Delaware Rapid Assessment Procedure for Freshwater Wetlands and the Guidance for Rating Wetland Values in Delaware for Assessing Wetland Restoration Projects

The Delaware Rapid Assessment Procedure for freshwater wetlands (DERAP) and the Guidance for Rating Wetland Values in Delaware (Value Added) were designed to quickly and quantitatively assess habitat characteristics of natural wetlands based on their hydrogeomorphic type (flat, depression, and riverine). This method scores and compares habitat, hydrology, and buffer stressors that occur in natural wetlands to other wetlands close to reference condition and provides insight into how they are functioning in a given watershed. In general, this method assumes, the more disturbed and less buffered a natural wetland is, the lower its score and ability to perform typical wetland functions (Jacobs, 2010 and Rogerson, 2014).

When considering the use of this method for restoration sites, the problem arises with the fact that all wetland restorations are inherently disturbed. The location, type of wetland created, and restoration method all determine the level of disruption that occurs. Some wetland restoration projects simply plug up a ditch in a fallow farm field and let the hydrology, plants, and wildlife return naturally (Jarzemsky, 2013). Others use extreme site manipulation such as berms, channels, ponds, ruts, and water control structures to "plant" the wetland in the landscape, as seen in the wetland restoration projects assessed for this project.

If using DERAP and Value Added to assess a natural wetland, the manipulations described above would be seen as negative impacts and count against the final score. But in wetland restorations, these actions are used to create the wetland, so considerations and further analyses need to be made when evaluating restored wetlands using these methods. The following are suggestions to consider improving the use of DERAP and Value Added for created or restored wetland.

Overall

- How a wetland is scored depends on the hydrogeomorphic (HGM) category and determining which HGM category restored wetlands fall into can sometime be tricky due to the method selected for site creation. Some wetland restorations appear to mimic a particular HGM type, while others do not. Instead of attempting to determine the type of HGM category the wetland restoration falls into for the DERAP and Value Added method, can all wetland restorations be scored on the same scale?
- The Qualitative Disturbance Rating (QDR) metric rates wetlands on a scale of 1 to 5 ranked from reference condition to most disturbed wetlands. Since restored wetlands are inherently disturbed as described above, this metric is unusable for this purpose and should be removed.

Habitat Stressors

- Dominant Forest Age – Currently the lowest bucket that exists is ≤2 years, and there is not a way to capture the lack of trees in the scoring. It would be useful to have a 0 bucket which would indicate that trees are not present in the site and have influence over the score. In the restoration sites we assessed, we did see a few locations in which trees died off due to beaver activity impounding water or the accidental spray of an herbicide, but there was no way to capture these issues.

- Presence of Nutrient Enrichment Indicator Species – This metric is intended to only be used in depression wetlands. As the restoration wetlands we visited did not fit neatly into one HGM type, should this metric apply to all restored wetlands? Alternatively, research has suggested that it is difficult to discern the meaning of the presence of nutrient enrichment indicator species in disturbed landscapes, and that the volume of these species may be more indicative than their presence alone (Craft, 2007). So, we also question based on our preliminary data if altered areas, such as wetland restoration sites, innately have a higher presence of nutrient enrichment indicator species?
- Active Management – This metric does not currently exist in DERAP. In a few of the wetland restoration sites assessed, DERAP site visits from 2009 to 2018 saw a decrease in the amount of invasive plant species from year to year due to active management of the site by mowing or aerial spraying. This information was discovered through conversations with the landowner or manager. If an intended goal of a wetland restoration assessment method is to capture improvements or declines in health over time and the reasons, the addition of this metric could provide a great deal of insight. An active management metric would not necessarily have to be captured in the scoring but could be referred to when analyzing the final score. This raises a whole other question about how restoration wetlands should be assessed. If the goal of a restoration assessment method is to look at changes over time, DERAP (even in a modified form) might not be the best method to use, as it represents a snapshot in time.

Hydrologic Stressors

- Weir/Dam/Road – A number of assessed wetland restoration sites contained water control structures. Examples of these structures included standpipes, overflow spillways, and tide gates. According to DERAP, this metric should be counted (and score reduced) if there is "any man-made structure in a wetland that is impacting the flow of water through a site by either impounding water in the site and/ or inhibiting water getting to the site" (Jacobs, 2010). But the question remains, if these wetland restoration projects didn't have a water control structure, would the wetland exist? Should this metric really count against a restored wetland? Also, berms are a commonly used tactic to allow water to collect and remain onsite. Are berms around a restored wetland a bad thing? Do they signify a project was put in the wrong place and hinder the wetland from being as effective as it should be? Or are berms simply man's engineered way to hold water and mimic the same natural processes?
- Flooding – The permanently flooded and inundated metrics are currently not taken account into the final scoring of each wetland. Most of these restored wetlands appeared to have a significant amount of water on their surface, and we wonder if this could impact the ability of this wetland to function to its fullest capacity now and into the future since sea levels are rising and Delaware is a low-lying state. One suggestion is to investigate the possibility of converting this unscored metric into a scored one by using data previously collected from natural wetlands with a QDR of 1 or 2 as baseline data. Considerations should be made in scoring so that naturally functioning wetter or drier wetlands would be least likely to be penalized.
- Filling or Excavation – This metric should remain, but the wording should be clarified to denote that these stressors do not pertain to the activities that occurred during the site's creation.

- Microtopographic Alteration – This metric warrants further investigation. As mentioned, wetland restoration sites inherently have microtopographic alteration that is due to the creation of the site (i.e. skidder tracks that are then planted with trees, and berms for retaining water). In addition, is there a degree to which an abundance of small elevation variability in the landscape is detrimental and creates a disconnect between microhabitats that may also promote the recruitment of invasive plant species or retainment of unwanted organisms?

Buffer Stressors

- Wetlands that are surrounded by a fully functioning buffer will be able to perform wetland functions to a higher degree. But restoration sites are not necessarily placed in areas that contain large contiguous undeveloped buffers. Wetlands surrounded by a decent buffer will perform better, but should we discredit it for having impacts in the buffer? The outcome of this metric depends on the big picture question being asked. If the condition of the wetland as a whole is to be looked at, then the buffer score does provide value. But, if the goal is to see if specific sites have met specific restoration goals, maybe the buffer shouldn't be taken into consideration.

Value Added

- The most beneficial section of the Value Added protocol to assess restored wetlands is the habitat structure and complexity section. It allows the assessor to quickly and easily see if the restored wetland contains habitat characteristics that are common in reference wetlands and promote a sustainable system. These data include a checklist of snags, large downed wood, coarse woody debris, microtopographic relief, and surface waters (Rogerson, 2014).

Status Review of Individual Wetland Restoration Sites

A status review of 14 individual wetland restoration sites was performed to determine if the restoration sites were indeed wetlands, determine the status of wetland function, and make management recommendations to improve the site's health and function. For the purpose of this review, we defined a wetland using the U.S. Army Corps of Engineers and the U.S. Environmental Protection Agencies' definition of "areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil condition." In other words, in order for the restoration site to be considered a wetland and be assessed as such for this study, it must have contained hydrophytic plants, wetland hydrology, and hydric soils. These three features can and were used as a basis to provide insight into wetland condition of the individual restored wetlands that follow.

Identifying plant species has long been used as a tool to help determine the health and function of wetlands (Mitsch, 1996). For this study we identified a number of vegetation characteristics, including hydrophytic plant species, invasive and nutrient indicator species, and plant debris to aide in an understanding of wetland condition. For example, snags, large downed wood, and course woody debris are all sources of food and homes for wildlife and organic matter that aid wetlands in performing their functions (Alsfeld, 2009).

Wetlands are also heavily dependent on water, and too much or too little water can have a rippling effect throughout the system. If the right balance between habitat, hydrology, and buffer considerations are not achieved, invasive species could be given the right conditions take over or plants could drown and die off (Boers, 2008, Keddy, 2000, Pierce, 2007 and Winter, 1988). To capture this, we classified wetland hydrology across the site using permanently flooded, inundated, and water depth metrics.

The effects of water across a wetland site can also be seen in the soil, but the extent of the effect depends on the duration of saturation. Restored wetlands are relatively young and usually involve sandy type soils that can sometimes be difficult to discern as hydric (Rossi, 2015). To garner an understanding of the soil conditions in these restored wetlands, we collected data on the depth of the organic layer, soil composition, and color using the Munsell Color Chart. If the mineral soil had a chroma value of 2 or less it was considered hydric for our purposes (Mitsch, 2015).

There are two sets of data for the individual wetland restoration assessments reported here. They have been classified into Repeat Site Visits and Single Year Site Visits. The Repeat Site Visits category reports on wetland restorations, performed either as a mitigation or voluntary effort, that were assessed in 2009 using Delaware Rapid Assessment Procedure for freshwater wetlands (DERAP) version 5.2, and in 2018/ 2019 using DERAP version 6, the Guidance for Rating Wetland Values in Delaware (Value Added) version 1.1, and additional metrics as described in the Methods section of this report.

The Single Year Site Visits section reports on only wetland assessments performed in 2018 or 2019 using DERAP version 6, the Guidance for Rating Wetland Values in Delaware (Value Added) version 1.1, and additional metrics as described in the Methods section of this report. The DERAP and Value Added protocols are intended to be used with natural wetlands, not restored. As such, only certain parameters within the protocols that provided insight into site performance along with additional metrics are reported here.

Repeat Site Visits

Zimmerman

Site Assessment

The Zimmerman restoration site was located on private property in the St. Jones River watershed and was created in 2002 by the Natural Resources Conservation Service (NRCS). It was primarily an upland restoration area that involved non-tidal freshwater wetland components. The site was created next to a tidally influenced wetland but separated by a berm and a one-way water control structure. In using site characteristics and best professional judgement, we categorized the site as a depression wetland for assessment purposes. Zimmerman was classified in Cowardin as a PFO1 and LLWW as TEFLOIed by assigning the codes from the closest wetland polygon.

Figure 18 Zimmerman restoration site. Green dot is the assessment area center, green circle is assessment area. Blue polygon is the 2007 DE wetlands layer.

The site was visited on October 5, 2009 and August 22, 2018 and assessed using the Delaware Rapid Assessment Procedure for freshwater wetlands (DERAP) versions 5.2 and 6 (respectively) and the Guidance for Rating Wetland Values in Delaware (Value Added) version 1.1 in 2018. The assessment area was a 40 meter radius with center coordinates of 39.08496, -75.47138.

2018 Status

No indicators of wetland hydrology were identified. Water was not present on the surface, and the permanently flooded metric was recorded as 0%. The site was also 1-25% inundated and no signs of recent inundation, such as dark staining, moss on tree trunks, or wrack lines, were seen.

Hydrophytic plants were present. The dominant plant species (≥55%) in individual assessment plots were trees and consisted of black gum (*Nyssa sylvatica*), sycamore (*Platanus occidentalis*), and river birch (*Betula nigra*). See plant list at end of section for a complete list of plant species noted in passing. Tree age was determined to be 16-30 years with 90% forestation. Comments were made about the existence of a high abundance of young saplings. The presence of invasive species was found to be 6-50% coverage with mint (*Mentha* spp.), Japanese honeysuckle (*Lonicera japonica*), and bamboo (*Babusa vulgaris*) being the prominent species. No nutrient enrichment indicator plant species were noted. Horizontal vegetation obstruction was determined to be 24%, which was redefined to a 76% open understory across assessment area plots.

Figure 19 Soil from Zimmerman site in 2018.

There were also no indicators of hydric soils, as the soil composition had no organic layer, was brown, crumbly and dry, and keyed out to 10YR 4/3 on the Munsell Soil Colorbook. No redox features were seen.

In 2018 the buffer surrounding the wetland assessment area contained the following stressors: residential development at less than or equal to one house per acre, two-lane paved roads, golf course, and a mowed path.

Using the Value Added Protocol, the presence or absence of habitat characteristics consistently found in high quality natural wetlands were captured. The Zimmerman site contained no snags, large downed wood, or surface water suitable for amphibians or fish. It did however contain course woody debris, microtopographic relief, and a tree canopy gap. Plant strata noted included herbs, shrubs, trees, and vines.

2018 Zimmerman Plant List (noted in passing)

black gum (*Nyssa sylvatica*), sycamore (*Platanus occidentalis*), river birch (*Betula nigra*), mint (*Mentha* spp.), Japanese honeysuckle (*Lonicera japonica*), bamboo (*Babusa vulgaris*), multiflora rose (*Rosa multiflora*), princess tree (*Paulownia tomentosa*), periwinkle (*Vinca major*), pow pow (*Asimina triloba*), Jack in the Pulpit (*Arisaema triphyllum*), poison ivy (*Toxicodendron radicans*), *Rubus* species (*Rubus* spp.), goldenrod (*Solidago* spp.), sweet gum (*Liquidambar styraciflua*), Virginia creeper (*Parthenocissus quinquefolia*), milkweed (*Asclepias* spp.), hickory (*Carya* spp.), oak (*Quercus* spp.)

2009 Status

In 2009, wetland hydrology was inferred from the permanently flooded and inundated metrics. Both metrics were reported as 0-25%.

Tree age was determined to be 3-15 years with 35% forestation. The presence of invasive species was determined to be 6-50% with mint (*Mentha* spp.), Japanese honeysuckle (*Lonicera japonica*) and bamboo (*Babusa vulgaris*) being the prominent species. No nutrient enrichment indicator plant species were noted.

The buffer surrounding the wetland assessment area contained the following stressors: residential development at less than or equal to one house per acre, two-lane paved roads, golf course, and a mowed path.

Discussion

As of the 2018 site visit, the Zimmerman restoration site did not contain all three wetland features. The site did not contain wetland hydrology or hydric soils but did contain hydrophytic plants. As such, the Zimmerman restoration site was not classified as a wetland for this study and no conclusions could be drawn for wetland condition. NRCS did not achieve the primary goal of creating a wetland. However, comments could be made about the existing plant community and suggestions for future improvements.

The dominant hydrophytic plants recorded in 2018 included black gum (*Nyssa sylvatica*), sycamore (*Platanus occidentalis*), and river birch (*Betula nigra*). These trees are typically found in Delaware's wetlands, but as this is a restoration site, we currently do not have the data to indicate whether these trees were planted or recruited naturally. Japanese honeysuckle (*Lonicera japonica*), multiflora rose

(*Rosa multiflora*), and bamboo (*Babusa vulgaris*)) are invasive plants that were identified and can be found in wetlands. But due to their invasive nature, they also can grow in other habitat types. Therefore, in our opinion, the presence of these plants alone is not enough to justify the Zimmerman site as a wetland.

A very small portion of the site exhibited landscape characteristics of freshwater depression wetlands, including bowl shape ground surface and microtopography (United State Department of Agriculture Natural Resources Conservation Service, 2008). A wood duck (*Aix sponsa*) house was also located in this area. This species depends on forested freshwater wetlands to survive the winter and reproduce (Dyson, 2018), and the presence of the bird house supports the hypothesis that the identified area was to be the intended location of the wetland.

The site also contained a berm with a water control structure that separated the non-tidal area from the tidal area. We pose the question, is this berm necessary as it changes the natural elevation of the landscape and inhibits possible future tidal marsh migration?

2009-2018 Changes

Although we cannot speak on the health of the wetland, we can identify a few informative habitat metrics. From 2009 to 2018 the tree age and forestation increased from 3-15 years old and 35% forested to 16-30 years old and 90% forested. This is to be expected as trees age and grow over time, but it is a decent increase in forestation. The presence of invasive plant species in 2009 to 2018 stayed 6-50% with the same plant species noted in both assessment years.

No notable change was seen from 2009 to 2018 in inundated and persistent water. The permanently flooded and inundated buckets differ from DERAP versions 5.2 and 6 with the addition of a solitary 0% bucket in DERAP version 6. With the changes in the protocol, it is hard to say if there was water present on the site or not in 2009, but at the time of the 2018 site visit there was absolutely no water visible on site. Buffer stressors held true for the 2009 and 2018 assessments.

Recommendations

The Zimmerman site is a part of the Delaware Ecological Network (DEN) which prioritizes areas of ecological importance based off the connectedness of the habitat to other natural areas. DEN demarcation is significant because it highlights the importance of the site to provide valuable habitat for wildlife and plant life and is a cause to embark on site improvements. If site improvements are desired, we recommend invasive species removal and management of site to restore proper growing conditions that allow native wetland vegetation to thrive (Hess, 2019). We also suggest an investigation to determine if the berm separating the restoration site from the tidal wetland is necessary as a habitat feature or if its removal would improve hydrology and allow for possible migration of the nearby tidal wetland. Lastly, the addition of large downed wood or creation of snags may provide additional habitat for wildlife and provide an additional source of organic material as they decay.

Little 1

Site Assessment

The Little 1 restoration site was located on private property in the St. Jones River watershed and was created in 2000 through the Natural Resources Conservation Service (NRCS). The site was a small shallow pond approximately 41 meters north to south and 38 meters east to west with minimal microtopography. The project contained a water control structure which drained to a nearby ditch, and mowed paths with seating areas for access to the site. Surrounding the wetland to the north was a stand of planted bald cypress trees (*Taxodium distichum*) in an upland area.

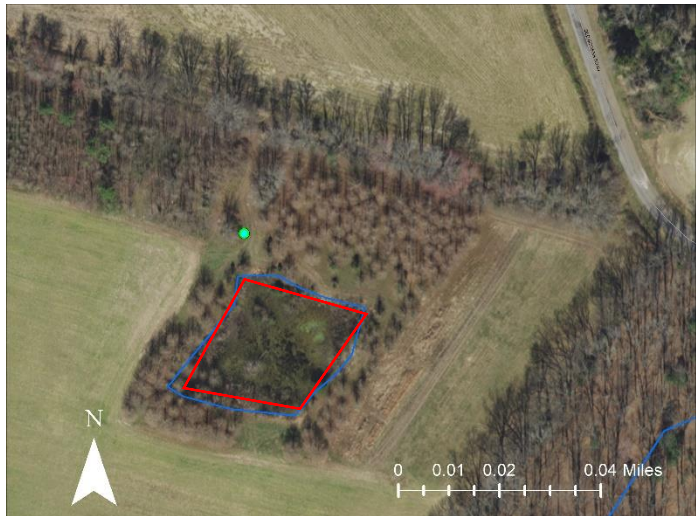

Figure 20 Little 1 assessment area highlighted by the red polygon. Green dot denotes approximate location of AA from the 2009 DERAP assessment. Blue lines are 2007 wetland demarcation.

Upon site visitation, the site was classified hydrogemorphically as a depression wetland in order to perform assessment work (United States Department of Agriculture Natural Resources Conservation Service, 2008). Little 1 is classified in Cowardin as a PEM1E and LLWW as TEBAIS.

The site was visited on October 6, 2009 and August 16, 2018 and assessed using the Delaware Rapid Assessment Procedure for freshwater wetlands (DERAP) versions 5.2 and 6 (respectively) and the Guidance for Rating Wetland Values in Delaware (Value Added) version 1.1 in 2018. The project was located at coordinates 39.05284, -75.42742, and the entirety of the wetland was assessed. Meter tapes were laid out in a plus sign with legs in the north, south, east and west cardinal directions. Eight vegetation plots sized at 1m^2 were laid out and assessed in 2018, 10.25m and 20.5m away from center on the north and south line transect lines, and 9.5m and 19m away from center on the east and west transect lines.

2018 Status

Wetland hydrology was classified as present through indicators of surface waters that were 13.56cm deep on average. The site was greater than 75% permanently flooded and inundated at greater than 75%.

Figure 21 Little 1 assessment area, north transect in 2018.

Hydrophytic vegetation was present with the dominant plant species consisting of duckweed (*Lemnoideae* spp.) and red maple (*Acer rubrum*). See plant list at end of section for complete list of plant species noted in passing. Tree age was determined to be 16-30 years with 10% forestation. The presence of invasive species was found to be 1-5% coverage with European reed

(*Phragmites australis* subsp. *australis*) and narrowleaf cattail (*Typha angustifolia*) being the prominent species. Nutrient enrichment indicator plant species were present at less than 50% with European reed (*Phragmites australis* subsp. *australis*), narrowleaf cattail (*Typha angustifolia*), spatterdock (*Nuphar advena*), barnyard grass (*Echinochloa crus-galli*) and algal mats. Horizontal vegetation obstruction was determined to be 36%. In other words, the understory in this wetland was 64% open.

The soil profile contained a 10cm deep organic layer and was composed of thick pieces of dead leaves and roots. The soil matrix at 20 cm deep was 100% very dark grayish brown and keyed out to 10YR 3/2 using the Munsell Soil Colorbook. No redox features were found.

Figure 22 Little 1 soil profile in 2018.

The buffer stressors recorded around the wetland assessment area in 2019 were two-lane paved roads, channelized stream or ditch, agricultural lands, and a mowed area.

Using the Value Added Protocol, the presence or absence of habitat characteristics consistently found in high quality natural wetlands were captured. The Little 1 site contained microtopography, surface water suitable for amphibians, and a tree canopy gap. It did not contain snags, large downed wood, surface water suitable for fish, or course woody debris. Plant strata noted included herbs, shrubs, and trees.

2018 Little 1 Plant List (noted in passing)

dotted smartweed (*Persicaria punctata*), winterberry holly (*Ilex verticillata*), black willow (*Salix negra*), spatterdock (*Nuphar advena*), barnyard grass (*Echinochloa crus-galli*), European reed (*Phragmites australis* subsp. *australis*), devil's beggartick (*Bidens frondosa*), narrowleaf cattail (*Typha angustifolia*), bald cypress (*Taxodium distichum*), marsh seedbox (*Ludwigia palustris*), duckweed (*Lemnoideae* spp.), red maple (*Acer Rubrum*), rice cutgrass (*Leersia oryzoides*), moss (*Sphagnum* spp.)

2009 Status

In 2009, wetland hydrology was inferred from the permanently flooded and inundated metrics. Both metrics were reported as 0-25%.

Tree age was determined to be 3-15 years with 35% forestation. The presence of invasive species was determined to be greater than 50% with narrowleaf cattail (*Typha angustifolia*) being the prominent species. Nutrient enrichment indicator plant species were noted at greater than 50% with narrowleaf cattail (*Typha angustifolia*) being the prominent species.

In 2009, the buffer surrounding the wetland assessment area contained the following stressors: two-lane paved roads, channelized stream or ditch, agricultural lands, and a mowed area.

Discussion

As of the 2018 site visit, the Little 1 site contained wetland hydrology, hydrophytic plants, and hydric soils. This data led to the conclusion that Little 1 is a wetland. Thus, NRCS's primary goal was achieved.

2009–2018 Site Changes

From 2009 to 2018, the presence of invasive species decreased from greater than 50% coverage to 1-5%, with narrowleaf cattail (*Typha angustifolia*) persisting through the years. Nutrient enrichment indicator species were found in both 2009 and 2018. In 2009, we estimated that there was a greater than 50% coverage of narrowleaf cattail (*Typha angustifolia*). In 2018, nutrient enrichment indicator species dropped to below 50% and included more of a variety of species including narrowleaf cattail (*Typha angustifolia*), spatterdock (*Nuphar advena*), European reed (*Phramites australis* subspp. *australis*), barnyard grass (*Echinochloa crus-galli*), and dense algal mats.

Tree age increased from the 3-15 years and 2% forested in 2009 to 16-30 years and 10% forestation in 2018, which was to be expected as trees grow with time. Since the 2009 assessment, the site stayed consistently flooded and inundated with water at the greater than 75% coverage bucket.

The buffer stressors held true for the 2009 and 2018 assessments.

Recommendations

The Little 1 ponded wetland provides habitat and cover for a variety of water-loving wildlife. Its site characteristics of plant density and diversity, and the absence of fish creates a suitable haven for amphibians to breed and grow (Shulse, 2012).

Research has shown that preemptive steps can be taken to reduce the likelihood of the takeover of invasive species, but if those efforts fail, the continual management of invasive species is crucial for the success of restoration projects (Keenleyside, 2012). As we spoke to the landowner during the site assessment, we discovered that he is continually mowing the invasive plants to reduce their presence. This is the most likely explanation for the reduction of invasive species between 2009 and 2018.

To continue to reduce the cover of invasive species, we recommend that the landowner continue to mow down the invasive plants. If further reduction of invasive species is warranted, the plant biomass and litter could be removed from the site, as this method has been shown to advance the recruitment of native plants and increase plant diversity (Lishawa, 2019).

Island Farms East and West

Site Assessment

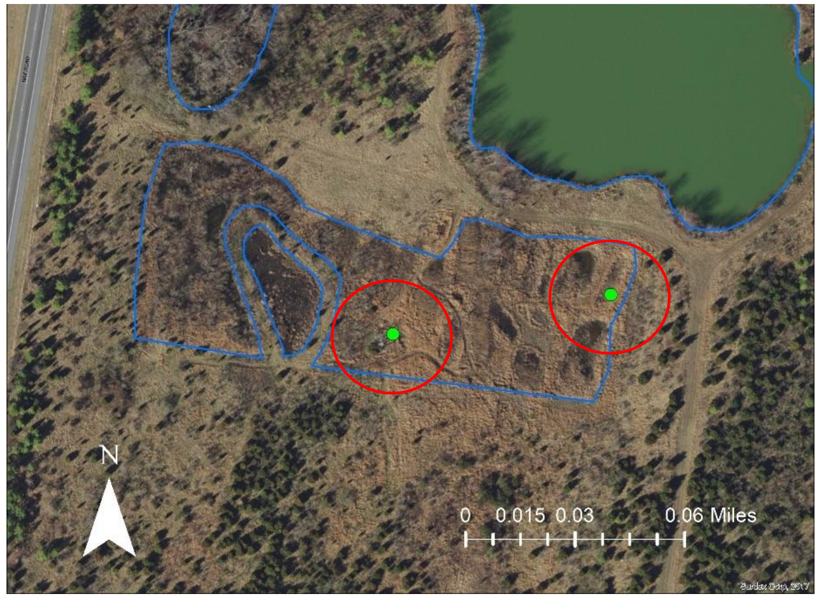

Figure 23 Island Farms wetland restoration project. 2007 mapped wetlands outlined in blue, green dots denote center and red circles denote east and west assessment areas.

The Island Farms restoration site was located on private property in the St. Jones River watershed and was created in 2002. The site was an open field that was used to create a wetland restoration project through the Natural Resources Conservation Service (NRCS). It consisted of a flat area with multiple dry, small, shallow depressions of varying sizes and depths, multiple grassy access paths for driving and walking to hunting sites, and shrubby vegetation. The site was located next to a large pond, and no inlet or outlet was seen in the restoration area.

In using our best professional judgement, the assessment areas were categorized as flat wetlands for assessment purposes (United States Department of Agriculture Natural Resources Conservation Service, 2008) due to the overall flat nature of the landscape. The multiple small and shallow depressions are not a feature found in natural wetlands, and thus made it hard to categorize properly. Islands Farms was classified in Cowardin as a PFO1 on state wetland maps.

The site was visited on October 5, 2009 and August 22, 2018 and assessed using the Delaware Rapid Assessment Procedure for freshwater wetlands (DERAP) versions 5.2 and 6 (respectively) and the Guidance for Rating Wetland Values in Delaware (Value Added) version 1.1 in 2018. This restoration site contained two assessment points: east (39.07803, -75.45609) and west (39.078076, -75.456919) to assess potentially two different wetland types that existed in the same area. Each assessment area was a 40-meter radius, and meter tapes were laid out in a plus sign with legs in the north, south, east and west cardinal directions. Eight vegetation plots sized at 1m^2 were laid out and assessed in 2018 on the east assessment point at each transect line 10 and 20 meters away from center. Due to the similarity of the east and west assessment areas, the additional metrics were only performed on the east assessment area in 2018.

2018 Status

Wetland hydrology was classified as present through the darker stained leaves and soil indicators. No surface water was seen at the time of the assessment. The site was 0% permanently flooded and inundated at 1-25%.

Hydrophytic vegetation was present in both assessment sites. There were no dominating plants in the east assessment area. See plant list at end of section for plant species noted in passing. Tree age was determined to be 16-30 years with 5% forestation in the east assessment area and 15% forestation in the west assessment area. The trees also appeared to be stunted. The presence of invasive species was found to be greater than 50% with autumn olive (*Elaeagnus umbullata*), bog bulrush (*Schoenoplectus mucronatus*), and European reed (*Phragmites australis* subspp. *australis*) being the prominent species in the east assessment area. In the west assessment area, the presence of invasive species was found to be 6-50%. Nutrient enrichment indicator species were determined to be present at less than 50% in both assessment sites, with flatsedge and nutsedge species (*Cyperus* spp.), narrowleaf cattail (*Typha angustifolia*), smooth rush (*Juncus effusus*), European reed (*Phragmites australis* subspp. *australis*) and black willow (*Salix negra*) being the prominent species. Horizontal vegetation obstruction was at 44% in the east assessment area. In other words, the understory was 56% open. Also worth noting was that there was a stand of dead groundsel bush (*Baccharis halimifolia*), a common tidal wetland plant, which appeared to be located in a higher/dryer area of the restoration site.

Figure 24 Island Farms East assessment area on the west transect line in 2018.

The soil profile contained a 4cm deep organic layer with a loamy, sandy, clay composition. The soil matrix at 20cm deep was 65% dark gray and keyed out to 10YR 4/1 using the Munsell Soil Colorbook. The redox features existing in the remaining 35% were a strong brown color and keyed out to 7.5 YR 4/6.

The single buffer stressor recorded around the assessment area in 2018 was a mowed area.

Using the Value Added Protocol, the presence or absence of habitat characteristics consistent in high quality natural wetlands were captured. The Island Farms site contained minimal snags, and an abundance of microtopography. It did not contain large downed wood, surface water suitable for amphibians or fish, or a tree canopy gap. Plant strata noted included herbs, shrubs, and trees.

Figure 25 Island Farms West assessment area on the west transect line in 2018.

2018 Island Farms Plant List (noted in passing)

autumn olive (*Elaeagnus umbullata*), bog bulrush (*Schoenoplectus mucronatus*), European reed (*Phragmites australis* subspp. *australis*), flatsedge and nutsedge species (*Cyperus* spp.), narrowleaf cattail (*Typha angustifolia*), smooth rush (*Juncus effusus*), black willow (*Salix negra*), groundsel bush (*Baccharis halimifolia*), smartweeds (*Persicaria* spp.), sweet gum (*Liquidambar styraciflua*), blackberry, rasberry or wineberry species (*Rubus* spp.), wool grass (*Scirpus cyperinus*), American water plantain (*Alisma subcordatum*), red maple (*Acer rubrum*), spikerush (*Eleocharis* spp.), horse nettle (*Solanum carolinense*), milkweed (*Asclepias* spp.), sedges (Carex spp.), grass-leaved goldenrod (*Euthamia* *grammifolia*), juniper (*Juniperus* spp.), crab apple (*Malus sylvestris*), marsh seedbox (*Ludwigia palustris*), unknown upland grass species

2009 Status

Due to the similarity of the east and west assessment sites, the following results are combined.

In 2009, wetland hydrology may be inferred from the permanently flooded and inundated metrics. Both metrics were reported as 0-25%.

Tree age was determined to be 3-15 years with 3% forestation in the east area and 5% forestation in the west area. The presence of invasive species was determined to be 6-50% with European reed (*Phragmites australis* subspp. *australis*) and narrowleaf cattail (*Typha angustifolia*) being the prominent species. Nutrient enrichment indicator species were noted at greater than 50% with black willow (*Salix nigra*) and narrowleaf cattail (*Typha angustifolia*) being the prominent species.

The buffer surrounding the wetland assessment area contained the following stressors: dirt or gravel road and mowed area.

Discussion

As of the 2018 site visit, the site contained all three characteristics of wetlands: hydrology, hydric soils, and hydrophytic plants, which led to the determination of a wetland. Thus, NRCS's primary goal was achieved. Note, assessment area does not encompass the wetland in its entirety.

2009–2018 Changes

From 2009 to 2018 the presence of invasive species increased from 6-50% to greater than 50% at the east site but stayed consistent at 6-50% in the west site. In both the east and west sites, nutrient enrichment indicator species decreased from greater than 50% coverage to less than 50% coverage. Tree age and forestation did slightly increase, which was to be expected as trees grow with time.

No notable change was seen from 2009 to 2018 in inundated and persistent water. The permanently flooded and inundated buckets differ from DERAP versions 5.2 and 6 with the addition of a solitary 0% bucket in DERAP version 6. With the changes in the protocol, it is hard to say if there was or was not water present in 2009, but both percent of site permanently flooded and percent site inundated metrics fell in the 0-25% range.

In 2009 the buffer surrounding the wetland assessment area contained dirt or gravel road and mowed area stressors. In 2018 the buffer just contained the single mowed area stressor, and it was noted that the road was now considered a mowed area.

Recommendations

If wetland improvements are desired, we recommend invasive plant management, and further studies into the Island Farms site's hydrologic function and elevation. We question whether or not the site is holding and processing water as intended, as it appears to be on the dry side and if proper elevations and optimal soil types were attained. Observationally we saw a significant die-off of the wetland plant groundsel bush (*Baccharis halimifolia*)) and are unsure if this is due to improper placement or another reason. Also, the higher spaces between the many-varied scale depressions appear to be facilitating invasive/upland plant growth that is encroaching on wetter areas of the site. To provide more habitat to attract wildlife and sources for organic material, we suggest adding large downed wood and course woody debris.

Scarborough

Site Assessment

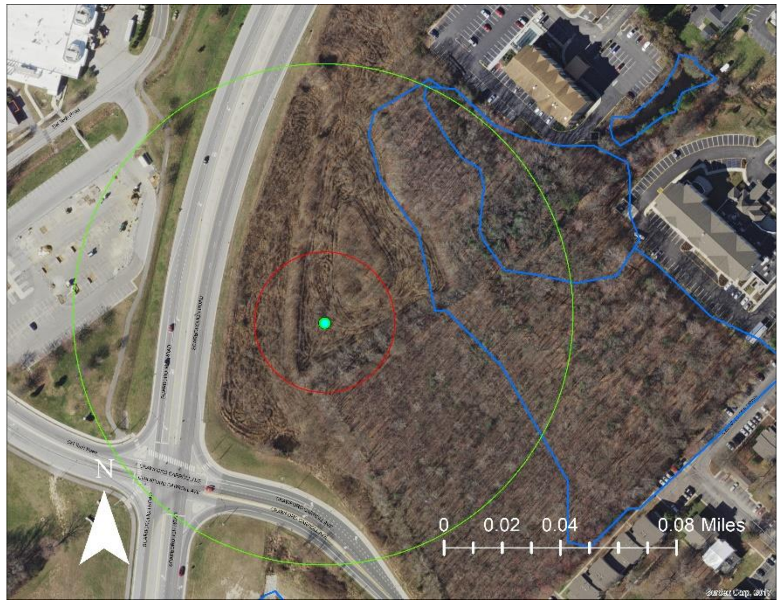

Figure 26 Scarborough assessment area in red, buffer in green, and 2007 mapped wetlands in blue. Green dot is assessment area center.

The Scarborough restoration site was a DelDOT wetland mitigation project in the St. Jones River watershed and was created in 2000. The site contained an abundance of microtopography that appeared to be consistent with tractor ruts, was dominated by planted oak trees, and was located adjacent to Scarborough Road and development. There were stormwater inputs, ponds, and a berm that extended approximately 50% of the site on the western edge. The eastern edge was an upland area with a large ditch on the perimeter of the site.

Upon site visitation, the site was classified hydrogeomorphically as a depression wetland for assessment purposes (United States Department of Agriculture Natural Resources Conservation Service, 2008). Scarborough currently has no classification in Cowardin or LLWW.

The site was visited on September 21, 2009 and August 2, 2018 and assessed using the Delaware Rapid Assessment Procedure for freshwater wetlands (DERAP) versions 5.2 and 6 (respectively) and the Guidance for Rating Wetland Values in Delaware (Value Added) version 1.1 in 2018. This restoration site was a 40-meter radius with a center point located at 39.19665, -75.5572. Meter tapes were laid out in a plus sign with legs in the north, south, east and west cardinal directions. Eight vegetation plots sized at 1m^2 were laid out and assessed in 2018 on each transect line 10 and 20 meters away from center.

Figure 27 Scarborough assessment area, south transect in 2018.

2018 Status

Wetland hydrology was classified as present through the indicators of surface waters that averaged 2.09cm across the assessment site. The site was 1-25% permanently flooded and inundated at 26-50%.

Hydrophytic vegetation was present and the dominant plant species in individual assessment plots consisted of red maple (*Acer rubrum*), willow oak (*Quercus phellos*), hickory (*Carya* spp.), and water oak (*Quercus nigra*). See plant list at end of section for plant species noted in passing. Tree age was determined to be 3-15 years with 100% forestation. The presence of invasive species was found to be 1-5%, with Japanese honeysuckle (*Lonicera japonica*), and European reed (*Phragmites australis* subspp. *australis*) being the prominent species. Nutrient enrichment indicator species were recorded at less than 50%, with European reed (*Phragmites australis* subspp. *australis*) being the prominent species. Horizontal vegetation obstruction was at 0%. In other words, the understory in this wetland was 100% open.

Figure 28 Scarbourough soil profile in 2018.

The soil profile contained a 2cm deep organic layer and a sandy-clay composition. The soil matrix at 20cm deep was 80% dark reddish gray and keyed out to 2.5YR 4/1 using the Munsell Soil Colorbook, Brown redox features made up the remaining 20% and keyed out to 7.5 YR 4/4. We are uncertain if the redox is due to the hydric nature of the soil or if it is remnant of the site creation as soils are commonly stirred up or brought in from other places in created wetlands.

The buffer stressors recorded around the assessment area in 2019 were commercial or industrial development, four-lane paved roads, channelized ditch, and a mowed area.

Using the Value Added Protocol the presence or absence of habitat characteristics consistent in high quality natural wetlands were captured. The Scarborough site contained large downed wood, course woody debris, an abundance of microtopography, and surface water suitable for amphibians. It did not contain snags, surface water suitable for fish or a tree canopy gap. Plant strata noted included herbs, shrubs, and trees.

2018 Scarborough Plant List (noted in passing)

Japanese honeysuckle (*Lonicera japonica*), European reed (*Phragmites australis* subspp. *australis*), southern arrowwood (*Viburnum dentatum*), smooth rush (*Juncus effusus*), fox grape (*Vitis labrusca*), Virginia creeper (*Pathenocissus quinquefolia*), swamp chestnut oak (*Quercus michauxii*), deertongue witchgrass (*Dichanthelium clandestinum*), *Rubus* spp., woolgrass bulrush (*Scirpus cyperinus*), tulip tree (*Liriodendron tulipifera*), willow oak (*Quercus phellos*), hickory (*Carya* spp.), red maple (*Acer rubrum*), water oak (*Quercus nigra*), sweet gum (*Liquidambar styraciflua*), moss (*Sphagnum* spp.), dotted smartweed (*Persicaria punctata*)

2009 Status

In 2009, wetland hydrology was inferred from the permanently flooded and inundated metrics. The site was recorded at 0-25% permanently flooded and 26-50% inundated.

Tree age was determined to be 3-15 years with 95% forestation. The presence of invasive species was determined to be 1-5%. No nutrient enrichment indicator plant species were noted.

The buffer surrounding the wetland assessment area contained the following stressors: commercial or industrial development, and four-lane paved roads.

Discussion

As of the 2018 site visit, the Scarborough site contained all three characteristics of wetlands: hydrology, hydric soils, and hydrophytic plants, and was determined to be a wetland. Thus, DelDOT's primary goal was achieved. Note, the assessment area did not encompass the wetland in its entirety.

2009–2018 Site Changes

From 2009 to 2018, the presence of invasive species remained constant at 1-5%, with Japanese honeysuckle (*Lonicera japonica*), and European reed (*Phragmites australis* subspp. *australis*). Nutrient enrichment indicator species were not recorded in 2009 but were in 2018 at less than 50% of European reed (*Phragmites australis* subspp. *australis*).

Tree age remained in the same 3-15 year bucket in 2009 and 2018, with forestation increasing from 95% to 100%.

No change was detected from 2009 to 2018 in inundated and persistent water. The permanently flooded metric was recorded as 0-25% in 2009 and 1-25% in 2018. The permanently flooded buckets differ from DERAP versions 5.2 and 6 with the addition of a solitary 0% bucket in DERAP version 6. With the changes in the protocol, it is hard to say if there was any water present in 2009 or not. The inundated metric fell in the 26-50% range for both assessment years.

The buffer surrounding the wetland assessment area contained the following stressors in 2009 and 2018 assessments: commercial or industrial development, and four-lane paved roads. The 2018 assessment also noted a channelized ditch and a mowed area. We assumed the difference in buffer stressors was due to an oversight in 2009 and not the development of new buffer stressors. The channelized ditch and mowed area are a part of the wetland itself and were made during the construction of the site.

Recommendations

At this time, we recommend invasive plant management at the Scarborough site to reduce the presence of Japanese honeysuckle (*Lonicera japonica*), and European reed (*Phragmites australis* subspp. *australis*).

Ted Harvey Logan Tract Site 1 & 2

Site Assessment

The Ted Harvey Logan Tract restoration site was located on state property in the St. Jones River watershed and was created in 2001 by the Delaware Department of Natural Resources and Environmental Control (DNREC). The site contained two excavated wetlands with island topography, flat filled areas, a berm splitting the two sites, and added large downed wood. There was also no water control structure in place.

Figure 29 Ted Harvey Logan Tract Site 1 (South) and Site 2 (North). Red lines are the outlines of the assessment areas. Blue lines are 2007 mapped wetlands.

Upon site visitation, the site was classified hydrogeomorphically as a depression wetland in order to perform assessment work (United States Department of Agriculture Natural Resources Conservation Service, 2008). The Ted Harvey Logan Tract sites were classified in Cowardin as a PSS1E and LLWW as LS4BATIhw.

The site was visited on October 5, 2009 and August 22, 2018 and assessed using the Delaware Rapid Assessment Procedure for freshwater wetlands (DERAP) versions 5.2 and 6 (respectively) and the Guidance for Rating Wetland Values in Delaware (Value Added) version 1.1 in 2018. This restoration site contained two assessment points: east (39.07803, -75.45609) and west (39.078076, -75.456919) to cover the two separate wetland cells. Each assessment area was shaped to the size of the wetland to attain a 0.5 hectare size, and meter tapes were laid out in a plus sign with legs in the north, south, east and west cardinal directions. Eight vegetation plots sized at 1m^2 were laid out and assessed in 2018 at each transect line.

2018 Status

Ted Harvey Logan Tract 1

Wetland hydrology was classified as present through the indicators of surface waters that were 7.13cm deep on average across the assessment area. The site was permanently flooded and inundated at 51-75%.

Figure 30 Ted Harvey Logan Tract 1 transect line in 2018.

Hydrophytic vegetation was present, with the dominant vegetation consisting of beggarticks (*Bidens* spp.) in the assessment area. See plant list at end of section for plant species noted in passing. Tree age was determined to be less than 2 years with 0% forestation. The presence of invasive species was found to be 1-5%. Nutrient enrichment indicator species were recorded at less than 50%, with dotted smartweed (*Persicaria punctata*) being the common species.

Horizontal vegetation obstruction was at 31%. In other words, the understory in this wetland was 69% open.

The soil profile contained an 8.5cm deep organic layer and a composition that was rooty with dense clay and sand. The soil matrix at 20cm deep was 98% dark gray and keyed out to 2.5YR 4/1 using the Munsell Soil Colorbook, and the redox made up the remaining 2% in a yellowish red color keyed out to 5YR 4/6.

The buffer stressors recorded around the assessment area in 2018 were: development at greater than two houses per acre, mostly two-lane paved roads, agricultural lands, and mowed areas.

The Ted Harvey Logan Tract 1 site contained snags, large downed wood, course woody debris, microtopography, and surface water suitable for amphibians and fish. The site did not contain a tree canopy gap, as the entire site was open canopy. Plant strata noted included herbs and vines.

Ted Harvey Logan Tract 2

Wetland hydrology was classified as present through the indicator of surface waters averaging 0.44cm deep across the assessment area. The site was considered permanently flooded at 1-25% and inundated at 26-50%.

Hydrophytic vegetation was present with the dominant vegetation consisting of marsh seedbox (*Ludwigia palustris*), red maple (*Acer rubrum*), and moss (*Sphagnum* spp.). See plant list at end of section for plant species noted in passing. Tree age was determined to be 3-15 years with 30% forestation. No invasive species were found at this site. Nutrient enrichment indicator species were recorded at greater than 50% with smooth rush (*Juncus effusus*) being the common species. Horizontal vegetation obstruction was at 24%. In other words, the understory in this wetland was 76% open.

Figure 31 Ted Harvey Logan Tract 2 transect line in assessment area in 2018..

The soil profile contained a 3cm deep organic layer and a composition that was mostly clay, and a few sand grains. The soil matrix at 20cm deep was 50% gray and keyed out to 2.5Y 5/1 using the Munsell Soil Colorbook. Redox features made up the remaining 50% in a dark yellowish-brown color that keyed out to 10YR 4/6.

The buffer stressors recorded around the assessment area in 2018 were: residential development at two houses per acre, two-lane paved roads, agricultural lands, and a mowed area.

The Ted Harvey Logan Tract 2 site contained snags, large downed wood, course woody debris, microtopography, and surface water suitable for amphibians. The site did not contain surface water suitable for fish, or a tree canopy gap. Plant strata noted included herbs, shrubs, and vines.

Figure 32 Ted Harvey Logan Tract 1 assessment area in 2009.

2018 Ted Harvey Logan Tract Plant List (noted in passing)

marsh seedbox (*Ludwigia palustris*), red maple (*Acer rubrum*), sphagnum moss (*Sphagnum* spp.), spikerush (*Eleocharis* spp.), trumpet vine (*Campsis radicans*), sweet gum (*Liquidambar styraciflua*), smooth rush (*Juncus effusus*), smartweed (*Persicaria* spp.), sedge (*Carex* spp.), bugleweed (*Lycopus* spp.), beggartick (*Bidens* spp.), mock bishop's weed (*Ptilimnium capillaceum*), climbing hempvine (*Mikania scandens*), fireweed (*Erechtites hieraciifolius*)

2009 Status

Ted Harvey Logan Tract 1

In 2009, wetland hydrology may be inferred from the inundated metric, which was recorded as greater than 75%. Permanently flooded was recorded at 0.

Tree age was determined to be 3-15 years with 20% forestation. The presence of invasive species and nutrient enrichment indicator species was determined to be greater than 50%, but no species were recorded on the data sheet.

The buffer surrounding the wetland assessment area contained the following stressors: development at less than or equal to one house per acre, mostly two-lane paved roads, and agricultural lands.

Figure 33 Ted Harvey Logan Tract 2 assessment area in 2009.

Ted Harvey Logan Tract 2

In 2009, wetland hydrology was inferred from the inundated metric, which was recorded as greater than 75%. Permanently Flooded was recorded at 0.

Tree age was determined to be 3-15 years with 30% forestation. The presence of invasive species and nutrient enrichment indicator species was determined to be greater than 50%.

The buffer surrounding the wetland assessment area contained the following stressors: two-lane paved roads, and agricultural lands.

Discussion

As of the 2018 site visit, both sites contained all three characteristics of wetlands: hydrology, hydric soils, and hydrophytic plants, and were determined to be wetlands. Thus, DNREC's primary goal was achieved. Note, assessment areas did not encompass the whole wetlands.

2009–2018 Site Changes

Ted Harvey Logan Tract 1

From 2009 to 2018, the presence of invasive species, nutrient enrichment indicator species, tree age, and forestation all decreased. The likely reason for this is due to the restoration project being inadvertently sprayed with herbicide during DNREC's Fish & Wildlife annual aerial spraying for European reed (*Phragmites australis* subspp. *australis*). In addition, the site saw an increase in the amount of visible water from 2009 to 2018. This could simply be due to the amount of rainfall, but further research would be needed to verify. Buffer stressors also increased around the assessment area due to housing development and enlarged mowed areas.

Ted Harvey Logan Tract 2

From 2009 to 2018, the presence of invasive species dropped from greater than 50% to 0%, while nutrient enrichment indicator species, tree age, and forestation remained the same. Again, this was likely due to the restoration project being inadvertently sprayed with herbicide during DNREC's Fish & Wildlife annual aerial spraying for European reed (*Phragmites australis* subspp. *australis*). Like Tract 1, an increase in the amount of visible water was documented from 2009-2018. Buffer stressors also increased around the assessment area due to housing development and enlarged mowed areas.

Recommendations

One recommendation is to ensure that herbicides are more carefully applied or that contingency plans are in place for replanting or reseeding areas that were unintentionally sprayed.

Island Carey 1

Site Assessment

The Island Carey 1 restoration site was located on state property in the St. Jones River watershed and was restored in 1996. The site contained many dead trees, European reed (*Phragmites australis* subspp. *australis*), several runoff drain inputs in the buffer, and was surrounded by a large ditch.

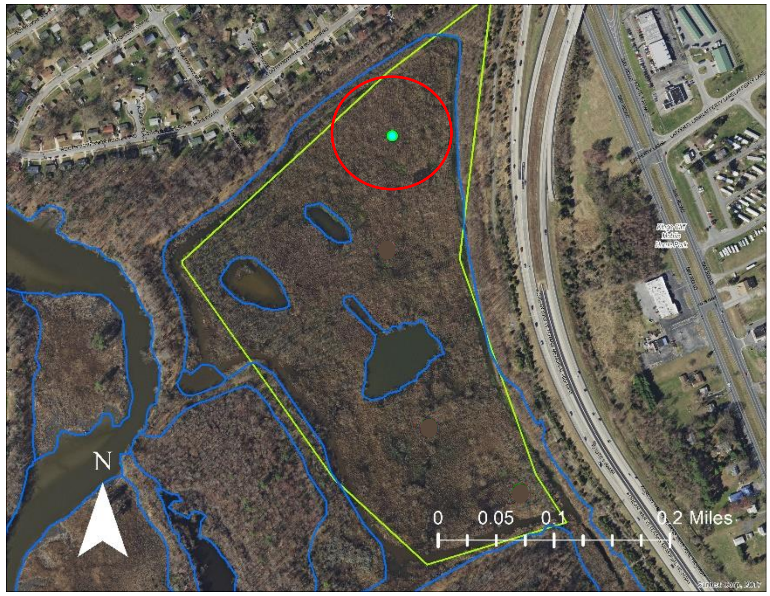

Figure 34 Island Cary wetland restoration site. Green dot represents center of assessment area, red circle represents assessment area. Green line denotes DelDOT mitigation extent, and blue line denotes 2007 mapped wetlands.

Upon site visitation, the site was classified hydrogeomorphically as a depression wetland in order to perform assessment work (United States Department of Agriculture Natural Resources Conservation Service, 2008). The Island Carey 1 site was classified in Cowardin as a PSS1/EM1C and LLWW as LS4BApdTIhw from state wetland maps.

The site was visited on October 22, 2009 and August 29, 2018 and assessed using the Delaware Rapid Assessment Procedure for freshwater wetlands (DERAP) versions 5.2 and 6 (respectively) and the Guidance for Rating Wetland Values in Delaware (Value Added) version 1.1 in 2018. This restoration site contained four assessment points, but only one assessment point was visited in both 2009 and 2018: Island Carey 1 (39.14024, -75.50079). The assessment area was a 40-meter radius, and meter tapes were laid out in a plus sign with legs in the north, south, east and west cardinal directions. Eight vegetation plots sized at 1m^2 were assessed at each transect line 10 and 20 meters away from center in 2018.

2018 Status

Wetland hydrology was classified as present through the indicator of surface waters that averaged to be 2.31cm deep across the assessment area. The site was 51-75% permanently flooded, and greater than 75% inundated.

Figure 35 Island Carey 1 assessment area in 2018.

Hydrophytic vegetation was present with European reed (*Phragmites australis* subspp. *australis*) dominating the cover. (See plant list at end of section for plant species noted in passing.) Tree age was determined to be less than 2 years with 0% forestation. The presence of invasive species was found to be greater than 50% with European reed (*Phragmites australis* subspp. *australis*) being the prominent species. Nutrient enrichment indicator species were recorded at greater than 50%, with *Carex* sp., smooth rush (*Juncus effusus)*, rice cutgrass (*Leersia oryzoides*), smartweeds (*Persicaria punctata*), and sedges (*Cyperus* spp.) being the prominent species. Horizontal vegetation obstruction was at 60%. In other words, the understory in this wetland was 40% open.

The soil profile contained a 13cm deep organic layer and a composition that was rooty. The soil matrix at 20cm deep was 99% olive brown and keyed out to 2.5Y 4/3 using the Munsell Soil Colorbook and composed mostly of sand with a few rocks. The redox made up the remaining 1%, but there was too little of the color to key out.

The buffer stressors recorded around the assessment area in 2019 were: development at greater than two houses per acre, channelized stream or ditch, and mostly dirt or gravel road.

The Island Carey 1 site contained snags, course woody debris, surface water suitable for amphibians and fish, and a tree canopy gap. It did not contain large downed wood or microtopography. Plant strata noted included herbs and vines.

2018 Island Carey Plant List (noted in passing)

European reed (*Phragmites australis* subspp. *australis*), false nettle (*Boehmeria cylindrica*), *Carex* spp., smooth rush (*Juncus effusus*), climbing hempweed (*Mikania scandens*), fern, red maple (*Acer rubrum*), willow oak (*Quercus phellos*), woolgrass bulrush (*Scirpus cyperinus*), black willow (*Salix negra*), hickory (*Carya* spp.), bugleweeds (*Lycopus* spp.), swamp loosestrife (*Decodon verticillatus*), rice cutgrass (*Leersia oryzoides*), poison ivy (*Toxicodendron radicans*), *Rubus* spp., dotted smartweed (*Persicaria punctata*), perfoliate thoroughwort (*Eupatorium serotinum*), sweet gum (*Liquidambar styraciflua*), pin oak (*Quercus palustris*), pennywort (*Hydrocotyle* spp.), sedges (*Cyperus* spp.), spikerush (*Eleocharis* spp.), duckweed (*Lemnoideae* spp.), beggartick (*Bidens* spp.), broadleaf arrowhead (*Sagittaria latifolia*)

2009 Status

In 2009, wetland hydrology was inferred as present from the permanently flooded (0-25%) and inundated (0-25%) metrics.

Tree age was determined to be 3-15 years with 45% forestation. The presence of invasive species was determined to be greater than 50%, with European reed (*Phragmites australis* subspp. *australis*) being the prominent species. Nutrient enrichment indicator plant species were noted at less than 50% and there were dense algal mats.

The buffer surrounding the wetland assessment area contained the following stressors: development at greater than two houses per acre, and channelized streams or ditches.

Discussion

As of the 2018 site visit, the site contained wetland hydrology and hydrophytic plants, but hydric soils were questionable. Even with the questionable soils, this site was still considered to be a wetland. Thus, DelDOT's primary goal was achieved. Note that the assessment site did not encompass the wetland in its entirety.

2009–2018 Site Changes

From 2009 to 2018 the presence of invasive species remained constant. Nutrient enrichment indicator species increased from 2009 and 2018 to greater than 50% coverage, while tree age and forestation were drastically diminished. According to DelDOT, in 2016 beaver impounded the area causing significant flooding for approximately four months. It was believed that this flooding lead to a die-off in the trees and a shift in the site hydrology. Beaver dams can create a lasting effect on the site (Johnston, 2001), and we did note increasing water levels over time in our assessments. The fire department also performed a training at this site and burned many of the young trees that had been planted, thus allowing European reed (Phragmites australis subspp. australis) to take over (Dunne, 2018). The buffer metrics remained relatively the same with only the addition of a small gravel or dirt road in 2018.

Recommendations

The Island Carey site is a part of the Delaware Ecological Network (DEN) which prioritizes areas of ecological importance based off the connectedness of the habitat to other natural areas. DEN demarcation is significant because it highlights the importance of the site to provide valuable connected habitat for wildlife and plant life and should be a priority habitat to maintain. With a greater than 50% coverage of invasive plant species persisting over the years, the top recommendation for improving conditions at the Island Carey 1 site is the management of invasive species. Secondly, because of the increase in permanently flooded water over the course of the 9-year period, we also would recommend that the site be monitored regularly for beaver activity and a further study of the hydrologic conditions be conducted. When water levels become and remain high in wetlands, plant die-off occurs.

Single Year Site Visits

Pollack

Site Assessment

Figure 36 Pollack DelDOT wetland mitigation site, denoted by green line, Bald Cypress complex to the east and Oaks complex to the west (green dot denotes assessment area center, red circle represents approximant assessment area). Blue line is 2007 mapped wetlands.

The Pollack Restoration site was located on state property in the Leipsic River Watershed and was created in the early 1990's. The project was managed by the Delaware Department of Transportation (DelDOT) as a mitigation project to offset the damages to wetlands that occurred during the creation of State Route 1 (SR1). The site was originally a cornfield that was then used as a borrow pit for the construction of SR1 and consisted of two different constructed wetland complexes (referred to in this report as Bald Cypress & Oaks). The wetlands were surrounded by steep, high berms which separated it from the Leipsic River and SR1, a small-lower berm with a water control structure that divided the two complexes, and a tide gate that remained closed, but connected the northeast Bald Cypress complex to the Leipsic River (Dunne, 2018)

Upon site visitation, the intended wetland type appeared to mimic a combination of freshwater deep swamps and shallow swamps (Penfound, 1952), and were classified hydrogeomorphically as depressional wetlands in order to perform assessment work (United States Department of Agriculture Natural Resources Conservation Service, 2008). Pollack was classified in Cowardin as PEMICx and LLWW as TEBAOU using state wetland maps.

The site was visited on August 31, 2018 and assessed using the Delaware Rapid Assessment Procedure for freshwater wetlands (DERAP) versions 6 and the Guidance for Rating Wetland Values in Delaware (Value Added) version 1.1. The restoration site contained two assessment points: one in the Bald Cypress complex (39.24105, -75.57488), and one in the Oaks complex (39.23932, -75.57578). Each assessment area was a 40-meter radius, and meter tapes were laid out in a plus sign with legs in the north, south, east and west cardinal directions. Eight vegetation plots sized at 1m^2 were laid out and at each transect line 10 and 20 meters away from center.

2018 Status

Pollack – Bald Cypress Complex

Wetland hydrology was classified as present through indicators of surface water that averaged to 19.75cm across the assessment area and evidence of changing water levels on the bark of trees. The site was greater than 75% permanently flooded and inundated at greater than 75%. It was noted that water levels have been known to reach approximately 3ft in the winter/spring and drop down to about 1ft in the summer/fall (Dunne, 2018).

Figure 37 Pollack - Bald Cypress Complex assessment area in 2018.

Hydrophytic vegetation was present. The dominant plant species (≥55% coverage) in individual assessment plots were bald cypress (*Taxodium distichum*) and duckweed (*Lemna* spp.). See plant list at end of section for plant species noted in passing. Tree age was determined to be 16-30 years with 100% forestation. The presence of invasive species was found to be greater than 50%, with European reed (*Phragmites australis* subspp. *australis*) being the prominent species. Nutrient enrichment indicator species were also found with an estimated greater than 50% coverage of smooth rush (*Juncus effusus)*, rice cutgrass (*Leersia oryzoides*), and European reed (*Phragmites australis* subspp. *australis*). Horizontal vegetation obstruction was 0%, which was redefined to 100% open understory across assessment area plots.

The soil profile contained a 3cm deep organic layer and a composition that was clay with little sand and uniform in color. The soil matrix at 20 cm deep was 80% gray and keyed out to 2.5Y 5/1 using the Munsell Soil Colorbook. The redox made up the remaining 20% at yellow and keyed out to 2.5y 7/6.

In 2018 there were no buffer stressors recorded around the assessment area, although there was a note regarding the height of the berms surrounding the complex.

The Pollack-Bald Cypress site contained course woody debris, microtopography, and surface water suitable for amphibians. It did not contain any snags, large downed wood, surface water suitable for fish, or a tree canopy gap. Plant strata noted included submerged aquatic vegetation, shrub and tree.

2018 Pollack – Bald Cypress Plant List (noted in passing)

bald cypress (*Taxodium distichum*), duckweed (*Lemna* spp.), marsh seedbox (*Ludwigia palustris*), smooth rush (*Juncus effusus*), red maple, (*Acer rubrum*), European reed (*Phragmites australis* subspp. *australis*), rice cutgrass (*Leersia oryzoides*), bulrush (*Scirpus* spp.)

Pollack – Oaks

Wetland hydrology was classified as present through the indicators of surface water that averaged to 15.75cm across the assessment area with evidence of variable water levels on tree bark. The site was greater than 75% permanently flooded and inundated at greater than 75%. In a site interview with Ken Dunne, it was also noted that a beaver had recently (prior to 2018) impounded water in this complex.

Hydrophytic vegetation was present. A variety of plant species were seen in this complex with only one plot containing a dominant species, willow oak (*Quercus phellos*). See plant list at end of section for plant species noted in passing. Tree age was determined to be 16-30 years with 100% forestation. There were no invasive species noted. Nutrient enrichment indicator species were found with an estimated less than 50% coverage of smooth rush (*Juncus effusus)*. Horizontal vegetation obstruction was at 27%. In other words, the understory was 73% open across assessment area plots.


Figure 38 Pollack - Oaks Complex assessment area in 2018.

The soil profile contained a 2cm deep organic layer and a composition that was clay with minimal sand. The soil matrix at 20 cm deep was 70% grayish brown and keyed out to 2.5Y 5/2 using the Munsell Soil Colorbook. The redox made up the remaining 30% at yellowish brown and keyed out to 10yr 5/6.

In 2018 there were no buffer stressors recorded around this assessment area, although there was a note regarding the height of the berms surrounding the complex.

The Pollack-Oaks site contained course woody debris, microtopography, and surface water suitable for amphibians and fish. It did not contain snags, large downed wood, or a tree canopy gap. Plant strata noted included submerged aquatic vegetation, herb, shrub and tree.

2018 Pollack – Oaks Plant List (noted in passing)

willow oak (*Quercus phellos*), marsh seedbox (*Ludwigia palustris*), bladderwort (*Utricularia* spp.), smooth rush (*Juncus effusus*), swamp chestnut oak (*Quercus michauxii*), water oak (*Quercus nigra*), elm (*Ulmus* spp.), poison ivy (*Toxicodendron radicans*), cinnamon fern (*Osmundastrum cinnamomeum*), red maple (*Acer rubrum*), sweet gum (*Liquidambar styraciflua*), moss (*Sphagnum* spp.), pin oak (*Quercus palustris*)

Discussion

As of the 2018 site visit, both the Pollack- Bald Cypress and Oaks assessment areas contained wetland hydrology, hydrophytic plants, and hydric soils, and were determined to be wetlands. Thus, DelDOT's primary goal was achieved. Note, assessment areas did not encompass the wetlands entirely.

Both complexes contained landscape characteristics similar to depression wetlands consisting of a bowl shape in the earth. Water appeared to be mostly from surface runoff, and evidence of seasonal water level variation on the trunks of trees was present (United States Department of Agriculture Natural Resources Conservation Service, 2008). However, the site contained extremely high berms and it was unclear how or if this unnatural feature will affect the connectivity of the site to the surrounding lands and waters into the future. Nutrient indicator species as defined in DERAP were also present in both complexes, but we questioned whether the presence of these species in restored wetlands was result of excess nutrients or an indicator of disturbance or succession (Craft, 2007).

The Pollack – Bald Cypress site observationally appeared to mimic a freshwater deep-water bald cypress swamp (Penfound, 1952), commonly found in Sussex County, Delaware. The northern most native range of these swamps exist in southern Delaware, but bald cypress (*Taxodium distichum*), have been planted all across the northern parts of Delaware in recent years as our program has discovered during annual wetland monitoring. The vegetation was dominated by bald cypress trees (*Taxodium distichum*) and duckweeds (*Lemna* spp.). The herbaceous layer was little to non-existent as evident by the horizontal vegetative obstruction measurement and is what we typically observe in this type of natural wetland. Future studies of the potential for salt water intrusion may be warranted due to the tide gate that is connected to the Leipsic River in this complex.

The Pollack – Oaks site observationally appeared to mimic a young shallow swamp, although the site was more inundated than one would typically see in this type of wetland in the summer (Penfound, 1952). This might be due in part to beaver activity. The vegetation was predominately oak trees (*Quercus* spp.), red maple (*Acer rubrum*), sweet gum (*Liquidambar styrciflua*), and smooth rush (*Juncus effusus*). The herbaceous layer was much more prevalent in this complex, as evident by the horizontal vegetative obstruction measurements. This may lead to the conclusion that this site was typically drier than the Bald Cypress complex, however, there was an average water depth of 15.75 cm across the assessment site at the time of visitation. Oak trees also require periods of inundation and dryness in order to properly germinate (Pierce, 2007)

In conclusion, both sites appear to have functional wetland qualities as it relates to plant communities, hydrology and soils. We would like to express concern over what appears to us to be high water levels for the summer season in each complex. Research has indicated that high water levels in swamps similar to these can lead to its decline and ultimately its demise, as plants may drown and reseeding is unlikely to occur (Middleton, 2006).

PNC

Site Assessment

The PNC site was located on state property in the Appoquinimink Watershed and was created in 1997. The project was managed by the Delaware Department of Transportation (DelDOT) as a mitigation project to offset the damages to wetlands that occurred during the creation of State Route 1 (SR1). The site was not planted. It was also stated that the elevation was improperly excavated, a drainage pipe was inappropriately placed, and a natural seep is believed to exist in the northwest corner (Dunne, 2018).

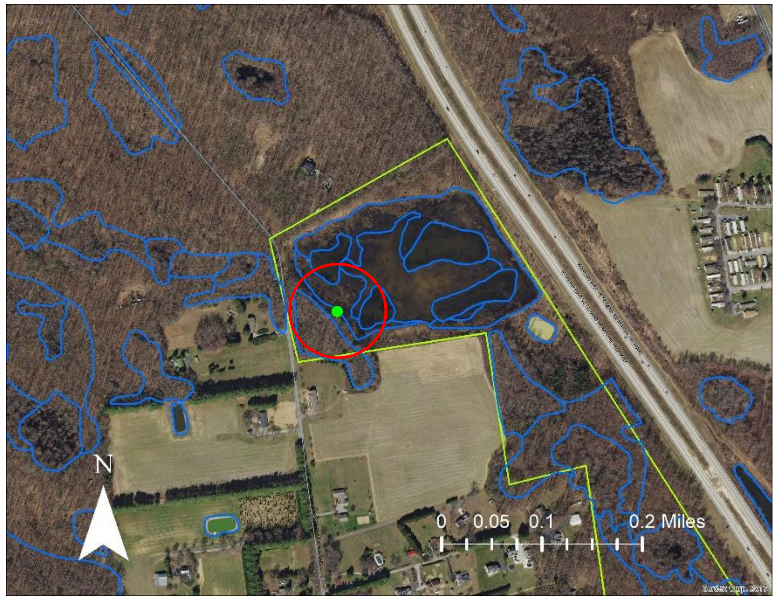

Figure 39 PNC DelDOT mitigation area (denoted by green line). Green dot denotes assessment area center, red circle denotes approximate assessment area, and blue lines highlighted 2007 mapped wetlands.

Upon site visitation, the site was classified hydrogeomorphically as a depressional wetland in order to perform assessment work (United States Department of Agriculture Natural Resources Conservation Service, 2008). PNC was classified in Cowardin as PEM1A and LLWW as TEFLpfIS on 2007 wetland maps. However, it was noted that the site was permanently flooded, and the Cowardin classification of "A" was incorrect.

The site was visited on August 30, 2018 and assessed using the Delaware Rapid Assessment Procedure for freshwater wetlands (DERAP) versions 6 and the Guidance for Rating Wetland Values in Delaware (Value Added) version 1.1. The restoration site contained one assessment point: 39.35516, -75.65394. The assessment area was a 40-meter radius, and meter tapes were laid out in a plus sign with legs in the north, south, east and west cardinal directions. Eight vegetation plots sized at 1m^2 were laid out and at each transect line 10 and 20 meters away from center.

2018 Status

Wetland hydrology was classified as present through the indicators of surface waters averaged to be 31.59cm across the assessment area. The site was greater than 75% permanently flooded and inundated at greater than 75%.

Figure 40 PNC assessment area in 2018.

Hydrophytic vegetation was present. Plots were open water or dominated by black willow (*Salix nigra*). See plant list at end of section for plant species noted in passing. Tree age was determined to be less than or equal to 2 years with 0% forestation. The presence of invasive species was found to be 1-5%, with narrowleaf cattail (*Typha angustifolia*) being the prominent species. Nutrient enrichment indicator species were also found, with an estimated less than 50% coverage of smooth rush (*Juncus effusus)*, smartweeds (*Persicaria spp.*), carex sedges (*Carex spp.*), and narrowleaf cattail (*Typha angustifolia*). Horizontal vegetation obstruction could not be performed at three of the plots due to water levels, and the third plot was 39% obstructed or alternatively, 61% open.

The soil profile contained no organic layer and the composition was uniformly sandy with some clay. The soil matrix at 20 cm deep was 100% dark grayish brown and keyed out to 2.5Y 4/2 using the Munsell Soil Colorbook. No redox features were found.

Figure 41 PNC soil profile in 2018.

In 2018 the buffer stressors recorded around the assessment area included development at less than or equal to 1 house per acre, two-lane paved roads, and agriculture.

Using the Value Added Protocol the presence or absence of habitat characteristics consistent in high quality natural wetlands were captured. The PNC site contained course woody debris, and surface water suitable for amphibians and fish. It did not contain any snags, large downed wood, microtopography, or a tree canopy gap. Plant strata noted included submerged aquatic vegetation, herb and shrub.

2018 PNC Plant List (noted in passing)

duckweed (*Lemna* spp.), marsh seedbox (*Ludwigia palustris*), smooth rush (*Juncus effusus*), red maple, (*Acer rubrum*), European reed (*Phragmites australis* subspp. *australis*), rice cutgrass (*Leersia oryzoides*), bulrush (*Scirpus* spp.), spatterdock (*Nuphar advena*), black willow (*Salix nigra*), (*Rubus* spp.), persimmon (*Diospyros virginiana*), spikerush (*Eleocharis* spp.), birch (*Betula* spp.), woolgrass (*Scirpus cyperinus*), smartweeds (*Persicaria* spp.), bugleweeds (Lycopus spp.), *Carex* sedges (*Carex* spp.), beggartick (*Bidens* spp.), narrowleaf cattail (*Typha angustifolia*)

Discussion

As of the 2018 site visit, the site contained wetland hydrology, hydrophytic plants, and hydric soils, and was determined to be a wetland. Thus, DelDOT's primary goal was achieved. Note, assessment area did not encompass the wetland in its entirety.

PNC appeared to be providing wildlife habitat to water loving wildlife species as evident from an abandoned beaver lodge, and sightings of fish, and birds. This was most likely due to the openness of the area and the abundance of food and water (Baldassarre, 2006, Collen, 2000, and Dorak, 2007).

Beaver have clearly impacted the area, resulting in the retention of water in the site. The average standing water over assessment area was over 30cm and inferred that the site has standing water all year round due to tree die-off, persimmon (*Diospyros virginiana*). Because the site retains so much water, questions remain as to how effective this pond is at providing ecoservices such as improving water quality or reducing the effects of climate change. While ponds do perform some water quality improving functions, there is research that suggests that ponds with stagnant waters and a lack of vegetation, such as PNC, do not have the necessary features to effectively reduce nutrient loads and total suspended sediments (Wong, 1999). It has also been suggested that varying water levels throughout the year can promote vegetation growth or regrowth, and aide in combating climate change through reduced methane emissions (Altor, 2006 and Keddy, 2000)

Therefore, if an interest in improving the functional capacity of PNC is desired, we recommend efforts to re-introduce annual hydrologic variability, additional microtopography or habitat features such as large downed wood and replant the site with vegetation capable of sustaining through long periods of inundation. These changes could allow this site to become a finely tuned feature for improving water quality and reducing greenhouse gas emissions in an agricultural landscape.

Thompsonville Cartanza

Site Assessment

Figure 42 Thompsonville Cartanza DelDOT mitigation site outlined in green. Green dot is center of assessment area, red circle is approximate assessment area, and blue lines denote 2007 mapped wetlands.

The Thompsonville Cartanza site was located on state property in the Leipsic River Watershed and was created between 1995 and 1996. The project was managed by the Delaware Department of Transportation (DelDOT) as a mitigation project to offset the damages to wetlands that occurred during the creation of State Route 1 (SR1). The site consisted of a scrub shrub young forested wetland and was very dry and confined by slopes on all sides.

Upon site visitation, the site was classified hydrogeomorphically as a flat wetland in order to perform assessment work (United States Department of Agriculture Natural Resources Conservation Service, 2008). Thompsonville Cartanza was classified in Cowardin as PEM1/SS1E and LLWW as LS1BApdTHhw on 2007 wetland maps. However, it was noted that the site was very dry and the Cowardin classification of "E" was incorrect.

The site was visited on August 8, 2018 and assessed using the Delaware Rapid Assessment Procedure for freshwater wetlands (DERAP) versions 6 and the Guidance for Rating Wetland Values in Delaware (Value Added) version 1.1. The restoration site contained one assessment point: 39.17487, -75.49545. The assessment area was a 94x28m rectangle, and meter tapes were fitted to the site. Eight vegetation plots sized at 1m^2 were laid out and at each transect line.

2018 Status


Figure 43 Thompsonville Cartanza transect line through assessment area in 2018.

Wetland hydrology was classified as present through the indicators of dry algae on the surface, although no surface water was seen. The site was 0% permanently flooded and inundated at 1-25%.

Hydrophytic vegetation was present. Dominant plant species seen in the assessment area were rice cutgrass (*Leersia oryzoides*), southern bayberry (*Morella cerifera*), and sweet gum (*Liquidambar styraciflua*). See plant list at end of section for plant species noted in passing. Tree age was determined to be 3-15 years with 30% forestation. The presence of invasive species was found to be 6-50%, with European reed (*Phragmites australis* subsp. *australis*), and barnyard grass (*Echinochloa crus-galli*) being the prominent species. Nutrient enrichment indicator species were also found, but since this wetland was assessed as a flat this metric was not scored (DERAP, 2010). Nutrient enrichment indicator species found included: smooth rush (*Juncus effusus)*, smartweeds (*Persicaria spp.*), algae, rice cutgrass (*Leersia oryzoides*), European reed (*Phragmites australis* subsp. *australis*), and barnyard grass (*Echinochloa crus-galli*). Horizontal vegetation obstruction was at 42%. In other words, the understory in this wetland was 58% open.

The soil profile contained a 3cm organic layer and the composition was very dry with compact clay. The soil matrix at 20 cm deep was 90% grayish brown and keyed out to 10YR 5/2 using the Munsell Soil Colorbook. The redox features consisted of 10% strong brown and keyed out to 7.5YR 4/6.

Figure 44 Thompsonville Cartanza, redox features from soil profile in 2018 sample.

In 2018 no buffer stressors were recorded around the assessment.

The Thompsonville Cartanza site contained no snags, large downed wood, course woody debris, microtopography, and surface water suitable for amphibians and fish. Plant strata noted included, herb, shrub, tree and vine.

2018 Thompsonville Cartanza Plant List (noted in passing)

duckweed (*Lemna* spp.), marsh seedbox (*Ludwigia palustris*), smooth rush (*Juncus effusus*), red maple, (*Acer rubrum*), European reed (*Phragmites australis* subspp. *australis*), rice cutgrass (*Leersia oryzoides*), black willow (*Salix nigra*), (*Rubus* spp.), persimmon (*Diospyros virginiana*), spikerush (*Eleocharis* spp.), woolgrass (*Scirpus cyperinus*), smartweeds (*Persicaria* spp.), bugleweeds (*Lycopus* spp.), *Carex* sedges (*Carex* spp.), climbing hempweed (*Mikania scandens*), false nettle (*Boehmeria cylindrica*), grass-leaved goldenrod (*Euthamia graminifolia*), broadleaf arrowhead (*Sagittaria latifolia*), barnyard grass (*Echinochloa crus-galli*), trumpet vine (*Campsis radicans*), loblolly pine (*Pinus taeda*), alien bulrush (*Schoenoplectiella mucronata*), rose mallow (*Hibiscus moscheutos*), spikerush (*Eleocharis* spp.), beggartick (*Bidens* spp.), southern bayberry (*Morella cerifera*)

Discussion

As of the 2018 site visit, the site contained wetland hydrology, hydrophytic plants, and hydric soils, and was determined to be a wetland. Thus, DelDOT's primary goal was achieved. Note, assessment area does not encompass the wetland in its entirety.

Habitat characteristics could be improved upon with the addition of snags, large downed wood, or course woody debris. The management of invasive plant species could also occur to prevent a take-over.

Poplar Hill

Site Assessment

The Poplar Hill site was located on state property in the St. Jones River Watershed and was created in 1997. The project was managed by the Delaware Department of Transportation (DelDOT) as a mitigation project to offset the damages to wetlands that occurred during the creation of State Route 1 (SR1). The site was a very large pond with an abundance of wildlife: fish, Canada geese, herons, and an abandoned beaver lodge.

Figure 45 Poplar Hill DelDOT mitigation site, outlined in green. Green dot represents center of assessment area, red circle represents approximate assessment area. Blue lines denote 2007 mapped wetlands.

Upon site visitation, the site was classified hydrogeomorphically as a depression wetland in order to perform assessment work (United States Department of Agriculture Natural Resources Conservation Service, 2008). Poplar Hill was classified in Cowardin as PUBHx and LLWW as PD3o1S using 2007 state wetland maps.

The site was visited on August 28, 2018 and assessed using the Delaware Rapid Assessment Procedure for freshwater wetlands (DERAP) versions 6 and the Guidance for Rating Wetland Values in Delaware (Value Added) version 1.1. The restoration site contained one assessment point located at 39.13589, -75.52471. The assessment area was a 40-meter radius, and meter tapes were laid out in a plus sign with legs in the north, south, east and west cardinal directions. Eight vegetation plots sized at 1m^2 were laid out and at each transect line 10 and 20 meters away from center.

2018 Status

Wetland hydrology was classified as present through the indicators of surface waters with an average depth of 37.38cm. The site was greater than 75% permanently flooded and inundated at greater than 75%.

Figure 46 Poplar Hill, transect line in assessment area in 2018.

Hydrophytic vegetation was present. No plants dominated the assessment plots, as they were all open water. See plant list at end of section for plant species noted in passing. Tree age was determined to be less than or equal to 2 years with 0% forestation. The presence of invasive species was found to be less than 1% with European reed (*Phragmites* *australis* subspp. *australis*) being the prominent species. Nutrient enrichment indicator species were estimated at 0% coverage, yet notation of smooth rush (*Juncus effusus)* and European reed (*Phragmites australis* subspp. *australis*) species was made. Horizontal vegetation obstruction could not be performed due to water levels.

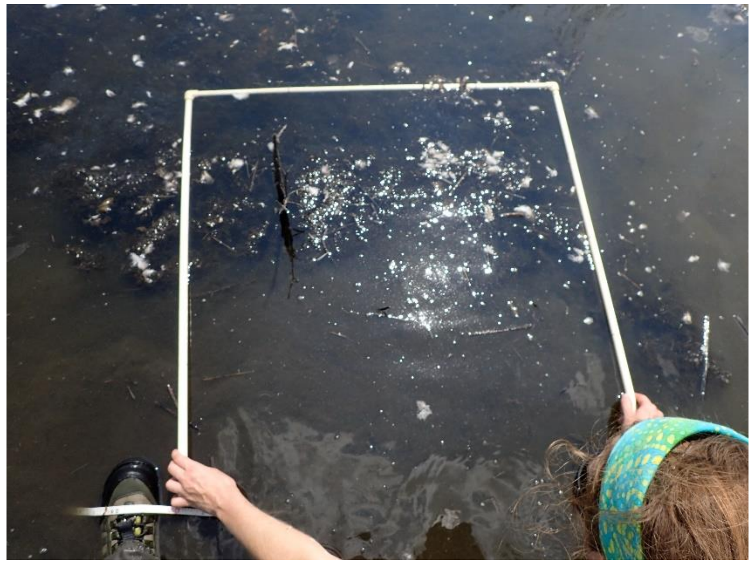

Figure 47 Poplar Hill plot in 2018 assessment. Note the abundance of feathers on water's surface.

The soil profile contained no organic layer and the composition was very sandy. The soil matrix at 20 cm deep was 100% dark yellowish brown and keyed out to 10YR 4/4 using the Munsell Soil Colorbook. No redox features were found.

In 2018 the buffer stressors recorded around the assessment area included 2-lane paved roads, and a mowed area.

The Poplar Hill site contained course woody debris, and surface water suitable for amphibians and fish. It did not contain any snags, large downed wood, microtopography, or a tree canopy gap. Plant strata noted included submerged aquatic vegetation, herb and shrub.

2018 Poplar Hill Plant List (noted in passing)

duckweed (*Lemna* spp.), marsh seedbox (*Ludwigia palustris*), smooth rush (*Juncus effusus*), red maple, (*Acer rubrum*), European reed (*Phragmites australis* subspp. *australis*), rice cutgrass (*Leersia oryzoides*), bulrush (*Scirpus* spp.), spatterdock (*Nuphar advena*), black willow (*Salix nigra*), (*Rubus* spp.), persimmon (*Diospyros virginiana*), spikerush (*Eleocharis* spp.), birch (*Betula* spp.), woolgrass (*Scirpus cyperinus*), smartweeds (*Persicaria* spp.), bugleweeds (*Lycopus* spp.), *Carex* sedges (*Carex* spp.), beggartick (*Bidens* spp.), narrowleaf cattail (*Typha angustifolia*)

Discussion

As of the 2018 site visit, the Poplar Hill site contained wetland hydrology and hydrophytic plants but contained questionable soils. Even with the soils in question, this site was considered a wetland, thus, DelDOT's primary goal was achieved. Note, assessment area did not encompass the wetland in its entirety.

Poplar Hill clearly provided wildlife habitat to water loving wildlife species, as was evident from an abandoned beaver lodge, and sightings of fish, Canada geese, and herons. This was most likely due to the openness of the area and the abundance of food and water (Baldassarre, 2006, Collen, 2000, and Dorak, 2007).

Beaver had clearly impacted the area, resulting in the retention of water in the site. But, as the average standing water over assessment area was over 30cm, questions remain as to the effectiveness of this pond in providing ecoservices such as improving water quality or reducing the effects of climate change.

While ponds do perform some water quality improving functions, research exists that suggest that ponds with stagnate waters and a lack of vegetation, such as Poplar Hill, do not have the necessary features to effectively reduce nutrient loads and total suspended sediments (Wong, 1999). It has also been suggested that varying water levels throughout the year can promote vegetation growth or regrowth, and aide in combating climate change through reduced methane emissions (Altor, 2006 and Keddy, 2000)

Therefore, if an interest in improving the functional capacity of Poplar Hill is desired, we recommend efforts to re-introduce annual hydrologic variability, additional microtopography or habitat features such as large downed wood and replant the site with vegetation capable of sustaining through long periods of inundation. These changes could allow this site to become a finely tuned feature for improving water quality and reducing greenhouse gas emissions in a developed landscape.

David

Site Assessment

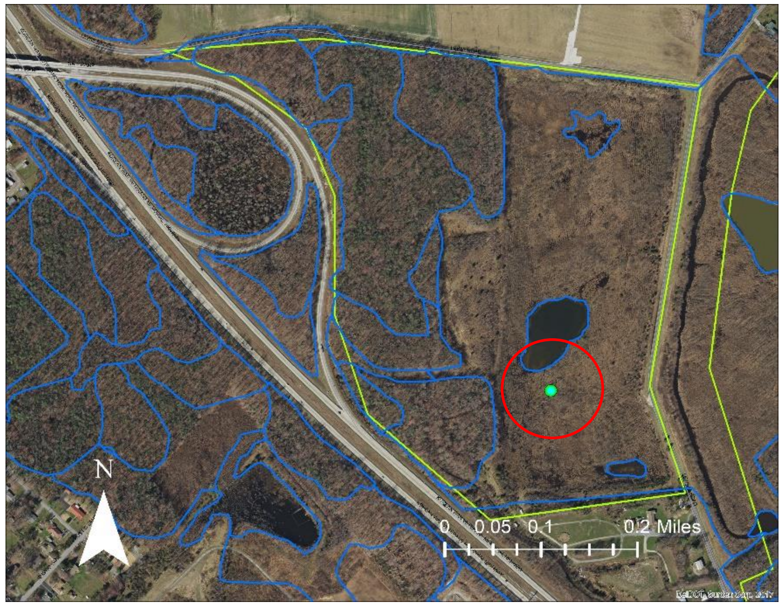

Figure 48 David DelDOT mitigation site, outlined in green. Green dot denotes center of assessment area, and red circle denotes approximate assessment area. Blue lines mark 2007 mapped wetlands.

The David site was located on state property in the Leipsic River Watershed and was created in the 1992. The project was managed by the Delaware Department of Transportation (DelDOT) as a mitigation project to offset the damages to wetlands that occurred during the creation of State Route 1 (SR1). The site was a wet meadow that was approximately 2m lower than the road elevation and surrounded by a berm that impounds water. Oak trees were planted in strips on the mounds of the skidder tracks. These tracks encompass the whole site, and in 2018 the only standing water was in the skidder ruts.

Upon site visitation, the site was classified hydrogeomorphically as a flat wetland in order to perform assessment work (United States Department of Agriculture Natural Resources Conservation Service, 2008). David was classified in Cowardin as HPEM1C and LLWW as TEBAOIhw using 2007 state wetland maps.

The site was visited on August 27, 2018 and assessed using the Delaware Rapid Assessment Procedure for freshwater wetlands (DERAP) versions 6 and the Guidance for Rating Wetland Values in Delaware (Value Added) version 1.1. The restoration site contained one assessment point located at 39.200583, -75.533048. The assessment area was a 40-meter radius, and meter tapes were laid out in a plus sign with legs in the north, south, east and west cardinal directions. Eight vegetation plots sized at 1m^2 were laid out and at each transect line 10 and 20 meters away from center.

Figure 49 David assessment area in 2018.

2018 Status

Wetland hydrology was classified as present through the indicators of surface waters contained in skidder ruts. The site assessment area had an average water depth of 0.88cm and was 1-25% permanently flooded and inundated at 26-50%.

Hydrophytic vegetation was present. The dominant plant species seen in the assessment area were swamp chestnut oak (*Quercus michauxii*), and red maple (*Acer rubrum*). See plant list at end of section for plant species noted in passing. Tree age was determined to be 16-30 years with 100% forestation. The presence of invasive species was found to be 6-50% with European reed (*Phragmites australis* subspp. *australis*), purple loosestrife (*Lythrum salicaria*) and narrowleaf cattail (*Typha angustifolia*) being the prominent species. Nutrient enrichment indicator species were estimated at 0% coverage as this parameter only applied to depression wetlands in DERAP. Although, the following species found at this site are considered to be nutrient enrichment indicator species in depressions: smooth rush (*Juncus effusus)*, European reed (*Phragmites australis* subspp. *australis*), dotted smartweed (*Persicaria punctata*), and narrowleaf cattail (*Typha angustifolia*). Horizontal vegetation obstruction was at 33%. In other words, the understory in this wetland was 67% open.

The soil profile contained an organic layer that was 4cm deep and composed of sandy clay with some uniform redox. The soil matrix at 20 cm deep was 65% weak red and keyed out to 2.5YR 5/2 using the Munsell Soil Colorbook. The redox features consisted of 35% strong brown and keyed out to 7.5YR 5/8.

Figure 50 David soil profile in 2018.

In 2018 no buffer stressors were recorded around the assessment area.

The David site contained microtopography and surface water suitable for amphibians. It did not contain snags, large downed wood, coarse woody debris surface water suitable for fish, or a tree canopy gap. Plant strata noted included herb, shrub, and tree.

2018 David Plant List (noted in passing)

sweet gum (*Liquidambar styraciflua*), southern bayberry (*Morella cerifera*), goldenrod (*Solidago* spp.), sensitive fern (*Onoclea sensibilis*), cinnamon fern (*Osmundastrum cinnamomeum*), deertongue witch grass (*Dichanthelium clandestinum*), fireweed (*Erichtites hieraciifolius*), water oak (*Quercus nigra*), purple loosestrife (*Lythrum salicaria*), poison ivy (*Toxicodendron radicans*), climbing hempweed (*Mikania scandens*), false nettle (*Bohemeria cylindrica*), flatsedges (*Cyperus* spp.), sphagnum moss (*Sphagnum* spp.), pin oak (*Quercus palustris*), marsh seedbox (*Ludwigia palustris*), smooth rush (*Juncus effusus*), red maple (*Acer rubrum*), European reed (*Phragmites australis* subspp. *australis*), black willow (*Salix nigra*), (*Rubus* spp.), spikerush (*Eleocharis* spp.), woolgrass (*Scirpus cyperinus*), smartweeds (*Persicaria* spp.), *Carex* sedges (*Carex* spp.), beggartick (*Bidens* spp.), narrowleaf cattail (*Typha angustifolia*), swamp chestnut oak (*Quercus michauxii*)

Discussion

As of the 2018 site visit, the David site contained wetland hydrology, hydrophytic plants, and hydric soils, which led to the conclusion that the site was a wetland. Thus, DelDOT's primary goal was achieved. Note, assessment area did not encompass the wetland in its entirety.

The David site contained invasive and nutrient enrichment indicator plant species. Invasive plants, such as narrowleaf cattail (*Typha* angustifolia), tend to dominate in disturbed landscapes, especially when little hydrologic variability occurs (Boers, 2008 and Bansal, 2019). Invasive plants create monotypic habitats, which can affect a wetland's ability to perform vital ecoservices and provide habitat to native wildlife populations (Kettenring, 2011). Additionally, we would like to point out that the presence and abundance of nutrient enrichment indicator plant species may be indicative of an altered landscape, and not necessarily due to the presence of increased nutrients (Craft, 2007)

One recommendation for improving site conditions is to institute a method that would allow for a larger variation in water levels throughout the year, which may help to combat the invasive species such as the narrowleaf cattail (*Typha angustifolia*) (Boers, 2008 and Bansal, 2019).

Sarro

Site Assessment

The Sarro site was located on state property in the Leipsic River Watershed and was created in the 1992. The project was managed by the Delaware Department of Transportation (DelDOT) as a mitigation project to offset the damages to wetlands that occurred during the creation of State Route 1 (SR1). The site was a depression type wetland that was enveloped by a mowed berm. Skidder tracks and standing water were present throughout the entire site.

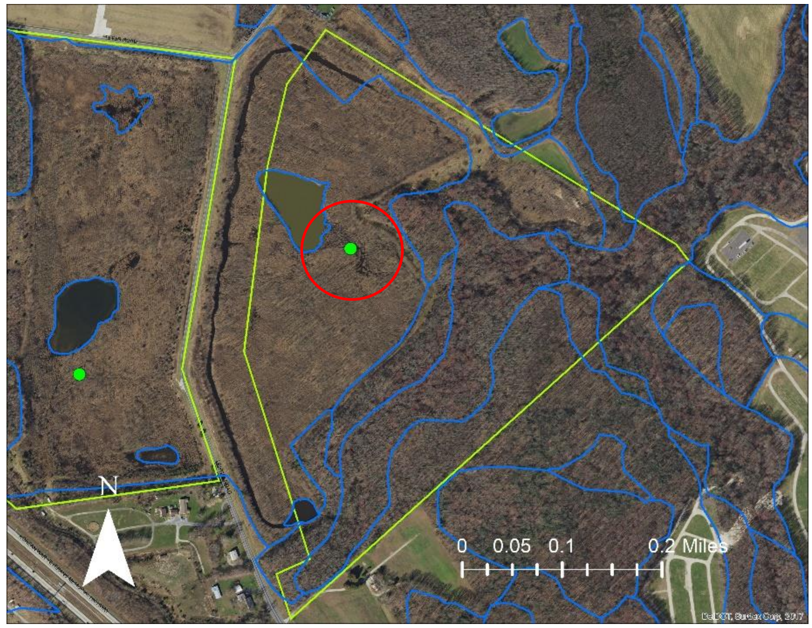

Figure 51 Sarro DelDOT mitigation site, right most outlined green polygon. East most green dot denotes center point of assessment area, and red circle denotes approximate assessment area. Blue lines denote 2007 mapped wetlands.

Upon site visitation, the site was classified hydrogeomorphically as a depression wetland in order to perform assessment work (United States Department of Agriculture Natural Resources Conservation Service, 2008). Sarro was classified in Cowardin as HPEM1C and LLWW as TEBAOIhw using 2007 wetland maps.

The site was visited on August 27, 2018 and assessed using the Delaware Rapid Assessment Procedure for freshwater wetlands (DERAP) versions 6 and the Guidance for Rating Wetland Values in Delaware (Value Added) version 1.1. The restoration site contained one assessment point located at 39.202413, -75.527993. The assessment area was a 40-meter radius, and meter tapes were laid out in a plus sign with legs in the north, south, east and west cardinal directions. Eight vegetation plots sized at 1m^2 were laid out and at each transect line 10 and 20 meters away from center.

2018 Status

Wetland hydrology was classified as present through the indicators of surface waters that averaged to be 36.91cm deep across the assessment area. The site was greater than 75% permanently flooded and inundated at greater than 75%.

Hydrophytic vegetation was present. Dominant vegetation across the Sarro assessment area consisted of sweet gum (*Liquidambar styraciflua*) and duckweed (*Leminoidae* spp.). See plant list at end of section for plant species noted in passing.


Figure 52 Sarro assessment area in 2018.

Tree age was determined to be 16-30 years with 80% forestation. The presence of invasive species was found to be 6-50%, with European reed (*Phragmites australis* subspp. *australis*) being the prominent species. Nutrient enrichment indicator species were estimated at less than 50% coverage with smooth rush (*Juncus effusus)* and European reed (*Phragmites australis* subspp. *australis*) being the dominant species. Horizontal vegetation obstruction was at 39%. In other words, the understory in this wetland was 62% open.

Figure 53 View of pond, west of the Sarro assessment area.

The soil profile contained no organic layer and the composition was sandy clay. The soil matrix at 20 cm deep was 75% dark grayish brown and keyed out to 10YR 4/2 using the Munsell Soil Colorbook. The redox features consisted of 25% strong brown and keyed out to 7.5YR 4/6.

In 2018 the only buffer stressor recorded around the assessment area was a channelized stream or ditch.

The Sarro site contained course woody, debris, microtopography, surface water suitable for amphibians and fish, and a tree gap. It did not contain snags, or large downed wood. Plant strata noted included submerged aquatic vegetation (SAV), herb, shrub, tree, and vine.

2018 Sarro Plant List (noted in passing)

Duckweed (*Lemna* spp), sweet gum (*Liquidambar styraciflua*), water oak (*Quercus nigra*), pin oak (*Quercus palustris*), smooth rush (*Juncus effusus*), red maple (*Acer rubrum*), European reed (*Phragmites australis* subspp. *australis*), black willow (*Salix nigra*), *Carex* sedges (*Carex* spp), bald cypress *(Taxodium distichum),* swamp chestnut oak (*Quercus michauxii*), crab apple (*Malus* spp.)

Discussion

As of the 2018 site visit, the Sarro site contained wetland hydrology, hydrophytic plants, and hydric soils, although no organic layer was present. This data led to the conclusion that Sarro is a wetland. Thus, DelDOT's primary goal was achieved. Note, assessment area did not encompass the wetland in its entirety.

The Sarro site contained invasive and nutrient enrichment indicator plant species. Invasive plants tend to dominate in disturbed landscapes, especially when little hydrologic variability occurs (Boers, 2008 and Bansal, 2019). Invasive plants create monotypic habitats which can affect a wetland's ability to perform vital ecoservices and provide habitat to native wildlife populations (Kettenring, 2011). Additionally, we would like to point out that the presence and abundance of nutrient enrichment indicator plant species may be indicative of an altered landscape, and not necessarily due to the presence of increased nutrients (Craft, 2007)

But, as the average standing water over assessment area was over 30cm and appears to remain at this level, questions remain as to how effective this ponded wetland is in providing ecoservices such as improving water quality or reduces the effects of climate change. While vegetated ponds do perform water quality improving functions, there is research that suggests that ponds with stagnate do not have the necessary features to effectively reduce nutrient loads and total suspended sediments (Wong, 1999). It has also been suggested that varying water levels throughout the year can promote vegetation growth or regrowth, and aide in combating climate change through reduced methane emissions (Aaron, 2007, Altor, 2006 and Keddy, 2000)

Therefore, if an interest in improving Sarro is desired, we recommend efforts to re-introduce annual hydrologic variability, additional microtopography or habitat features such as large downed wood and/or course woody debris, and management of the invasive species. These changes could allow this site to become a finely tuned feature for improving water quality and providing wildlife habitat.

Hall

<u>Site Assessment</u>

The Hall site was located on state property in the Smyrna River Watershed and was created in 1998. The project was managed by the Delaware Department of Transportation (DelDOT) as a mitigation project to offset the damages to wetlands that occurred during the creation of State Route 1 (SR1). The site was a depression type wetland that is enveloped by berm. SR1 borders the site to the west, and an agricultural field borders the site to the east. The site contained a natural-looking unidirectional overflow that drains into Mill Creek. Standing water was present across the entire site.

Figure 54 Hall DelDOT mitigation site outline in green. Green dot denotes center of assessment area, red rectangle denotes approximate size of assessment area. Blue lines outline 2007 mapped wetlands.

Upon site visitation, the site was classified hydrogeomorphically as a depression wetland in order to perform assessment work (United States Department of Agriculture Natural Resources Conservation Service, 2008). Hall was classified in Cowardin as PUBFx and LLWW as PD3o0Ied using 2007 state wetland maps.

The site was visited on August 21, 2018 and assessed using the Delaware Rapid Assessment Procedure for freshwater wetlands (DERAP) versions 6 and the Guidance for Rating Wetland Values in Delaware (Value Added) version 1.1. The restoration site contained one assessment point located at 39.202413, -75.527993. The assessment area was an 80m x 38m rectangle, and meter tapes were laid out in a configuration that fit the site. Eight vegetation plots sized at 1m^2 were laid out and at each transect line.


Figure 55 Hall assessment area, north transect line in 2018.

<u>2018 Status</u>

Wetland hydrology was classified as present through the indicators of surface waters that averaged to be 23.00cm deep across the assessment area. The site was greater than 75% permanently flooded and inundated at greater than 75%.

Hydrophytic vegetation was present. No dominant plant species were recorded in assessment area, although open water was a high occurrence. See plant list at end of section for plant species noted in passing. Tree age was determined to be 3-15 years with 1% forestation. The presence of invasive species was found to be greater than 50% with European reed (*Phragmites australis* subspp. *australis*) and narrowleaf cattail (*Typha angustifolia*) being the prominent species. Nutrient enrichment indicator species were estimated at greater than 50% coverage with smooth rush (*Juncus effusus)*, European reed (*Phragmites australis* subspp. *australis*), narrowleaf cattail (*Typha angustifolia*), and smartweeds (*Persicaria* spp.) being the dominant species. Algae were also present. Horizontal vegetation obstruction was at 45%. In other words, the understory in this wetland was 56% open.

Figure 56 Hall vegetation plot in 2018.

The soils surface was covered with water and a suitable sample could not be extracted.

The buffer stressors recorded around the assessment area in 2018 were less than or equal to two residential houses an acre, four-lane paved roads, channelized stream or ditch, and agricultural lands.

The Hall site contained snags, course woody, debris, surface water suitable for amphibians, and a tree gap. It did not contain large downed wood, microtopography, or surface water suitable for fish. Plant strata noted included submerged aquatic vegetation (SAV) and herb.

2018 Hall Plant List (noted in passing)

pickerelweed (*Pontederia cordata*), narrowleaf cattail (*Typha angustifolia*), poison ivy (*Toxicodendron radicans*), American water plantain (*Alisma subcordatum*), duckweed (*Lemna* spp), rose mallow (*Hibiscus moscheutos*), swamp dock (*Rumex verticillatus*), wild rice (*Zizania aquatica*), marsh seedbox (*Ludwigia palustris*), barnyard grass (*Echinochloa crus-galli*), fireweed (*Erechtites hieraciifolius*), dotted smartweed (*Persicaria punctata*), broadleaf arrowhead (*Sagittaria latifolia*), woolgrass bulrush (*Scirpus cyperinus*), smooth rush (*Juncus effusus*), red maple (*Acer rubrum*), European reed (*Phragmites australis* subspp. *australis*), black willow (*Salix nigra*), Japanese honeysuckle (*Lonicera japonica*), Virginia creeper (*Parthenocissus quinqufolia*), rice cutgrass (*Leersia oryzoides*), sphagnum moss (*Sphagnum* spp.)

Discussion

As of the 2018 site visit, the Hall site contained wetland hydrology, hydrophytic plants, and hydric soils, although no organic layer was present. This data led to the conclusion that Hall is a wetland. Thus, DelDOT's primary goal was achieved. Note, assessment area did not encompass the wetland in its entirety.

The Sarro site contained invasive and nutrient enrichment indicator plant species. Invasive plants tend to dominate in disturbed landscapes, especially when little hydrologic variability occurs (Boers, 2008 and Bansal, 2019). Invasive plants create monotypic habitats which can affect a wetlands ability to perform vital ecoservices and provide habitat to native wildlife populations (Kettenring, 2011). Additionally, we would like to point out that the abundance of nutrient enrichment indicator plant species may also be indicative of an altered landscape, but algae was also present indicating that excess nutrients may indeed be influencing the wetland (Craft, 2007).

If improvements to the Hall site are desired, we recommend efforts to manage the abundant invasive species present.

Hurd

Site Assessment

Figure 57 Hurd DelDOT mitigation site outlined in green. Green dot denotes assessment area center, red circle denotes approximate assessment area. Blue lines outline 2007 mapped wetlands.

The Hurd site was located on state property in the Smryna River Watershed and was created in the 1998. The project was managed by the Delaware Department of Transportation (DelDOT) as a mitigation project to offset the damages to wetlands that occurred during the creation of State Route 1 (SR1). The site was a forested flat type wetland that is connected to a pond and was created on a previously agricultural site. Agricultural fields and houses border the site on all sides. Standing water was present across the entire site.

Upon site visitation, the site was classified hydrogeomorphically as a depression wetland in order to perform assessment work (United States Department of Agriculture Natural Resources Conservation Service, 2008). Hurd was classified in Cowardin as PSS1E and LLWW as TEBApdIS using 2007 state wetland maps.

The site was visited on June 18, 2019 and assessed using the Delaware Rapid Assessment Procedure for freshwater wetlands (DERAP) versions 6 and the Guidance for Rating Wetland Values in Delaware (Value Added) version 1.1. The restoration site contained one assessment point located at 39.30241, -75.53095. The assessment area was a 40-meter radius, and meter tapes were laid out in a plus sign with legs in the north, south, east and west cardinal directions. Eight vegetation plots sized at 1m^2 were laid out and at each transect line 10 and 20 meters away from center.

2018 Status

Figure 61 Hurd, east transect line in the assessment area in 2019.

Wetland hydrology was classified as present through the indicators of surface waters that averaged to be 7.44cm deep across the assessment area. The site was greater than 75% permanently flooded and inundated at greater than 75%.

Hydrophytic vegetation was present with the dominant vegetation consisting of willow oak (*Quercus phellos*), and pin oak (*Quercus palustris*). See plant list at end of section for plant species noted in passing. Tree age was determined to be 16-30 years with 100% forestation. The presence of invasive species was found to be 1-5% with European reed (*Phragmites australis* subspp. *australis*) being the prominent species. Nutrient enrichment indicator species were recorded at 0% since this was assessed as a flat wetland, although European reed (*Phragmites australis* subspp. *australis*) is considered a nutrient enrichment indicator species. Horizontal vegetation obstruction was at 12%. In other words, the understory in this wetland was 88% open.

Figure 62 Redox features from soil profile of Hurd site in 2019.

The soil profile contained a 2cm deep organic layer and was composed of leaf litter and fibrous materials. The soil matrix at 20 cm deep was 80% gray and keyed out to 5Y 5/1 using the Munsell Soil Colorbook. The redox features consisted of 20% yellowish red and keyed out to 5YR 5/6. It was composed of mostly clay with a minor amount of sand.

The buffer stressors recorded around the assessment area in 2019 were development of less than or equal to 1 residential house an acre, and two-lane paved roads.

The Hurd site contained course woody debris, surface water suitable for amphibians and fish. It did not contain snags, large downed wood, microtopography, or a tree gap. Plant strata noted included tree.

2018 Hurd Plant List (noted in passing)

duckweed (*Lemna* spp), marsh seedbox (*Ludwigia palustris*), smartweed (*Persicaria* spp.), European reed (*Phragmites australis* subspp. *australis*), shallow sedge (*Carex lurida*), pin oak (*Quercus palustris*), tall switchgrass (*Panicum virgatum*), willow oak (*Quercus phellos*), persimmon (*Diospyros virginiana*), spikerush (*Eleocharis* spp.), sphagnum moss (*Sphagnum* spp.), sweet gum (*Liquidambar styraciflua*), ash tree (*Fraxinus* spp.)

Discussion

As of the 2019 site visit, the Hurd site contained wetland hydrology, hydrophytic plants, and hydric soils although no organic layer was present. This data led to the conclusion that Hurd was a wetland. Thus, DelDOT's primary goal was achieved. Note, assessment area did not encompass the wetland in its entirety.

The presence of invasive species was minimal, but to ensure that it does not take over the restoration project, we recommend the continual monitoring and or management of the invasive species.

Conclusion

Delaware's Natural Wetlands

As of 2017, Delaware was host to roughly 296,000 acres of wetlands that vary in salinity, soil type and vegetation based on geographic location and water source. With twenty percent of the state's land area consisting of wetlands, citizens and visitors to Delaware are surrounded by these hard-working natural features. Situated between water and land wetlands are highly adapted to particular conditions and provide many important services that support the state's economy. Wetlands naturally come in many different forms which dictate the myriad of plant and wildlife species, some rare and endemic species, as well as commercially harvested species that call them home.

Wetlands can generally be classified into tidal and non-tidal categories, and for this project the focus remained primarily on non-tidal wetlands (hydrogeomorphic (HGM) categories: flats and depressions). In Delaware non-tidal wetlands are freshwater, found around inland areas, and do not have tidal influxes of water. They are fed by rain, snow, or groundwater, and have variable water levels where land is usually covered with water during the winter and spring months and often dry on the surface during the summer or fall months.

Wet flatwood forests, or "flats," are one of the most common types of non-tidal wetlands in Delaware. Due to their seasonally wet nature, they often appear dry on the surface. The dominant water source is generally precipitation; however, groundwater has some contribution to these systems (Figure 60). They occur as mixed hardwood forests in the upper reaches of most watersheds, and as loblolly pine/maple-gum forests in areas on the edges of the Inland Bays. A variety of other wetland and upland plants also share this habitat. Flats provide large even

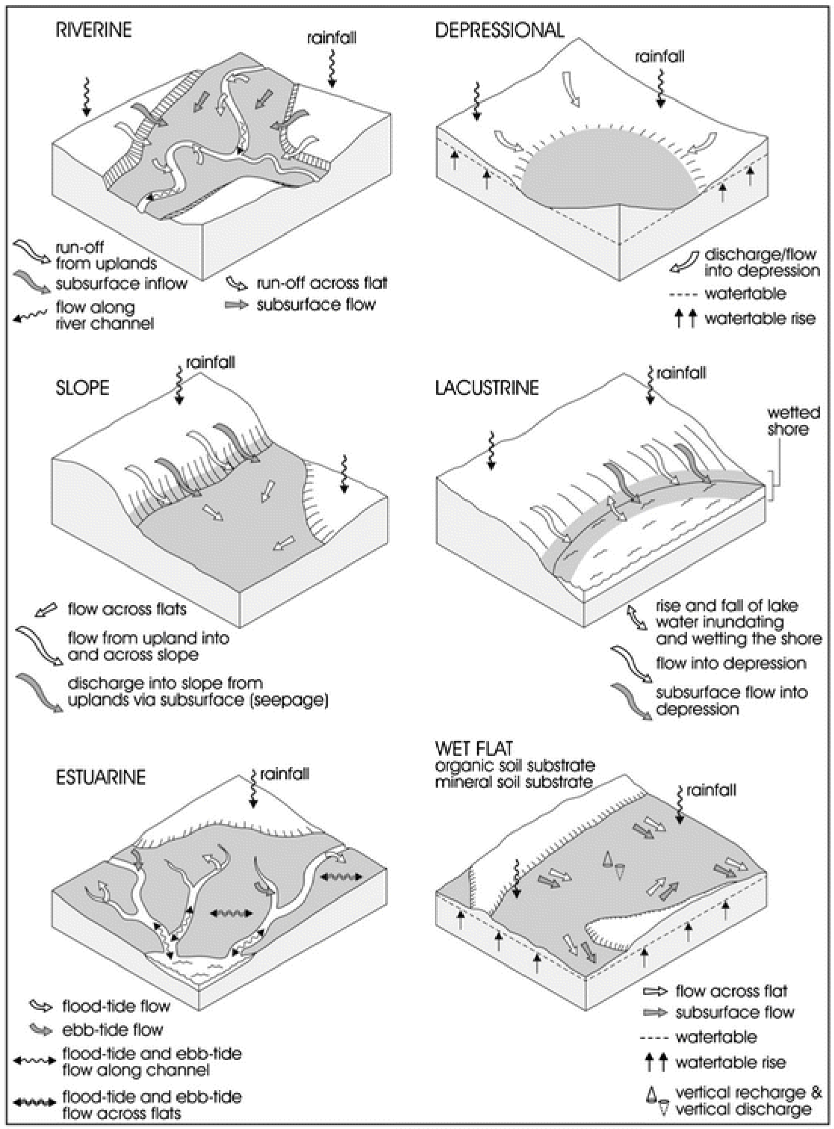

Figure 63 Hydrology and landscape position of natural wetland types. Reproduced for educational purposes (Semeniuk, 2018).

areas that can filter pollutants from water coming off the surrounding lands before they reach streams and are thus critical to maintaining water quality downstream. Flats also provide habitat for many wildlife species, such as birds, turtles, and deer.

Depression wetlands are non-tidal, isolated circular or elliptical shallow pools of water that occur in low-lying indentations in the land. These wetlands may have any combination of inlets and outlets or lack them completely, and water predominantly flows from higher elevations toward the center of the depression. They are fed by groundwater, rainfall, or snow melt in the winter and spring and usually dry up in the summer and fall (Figure 60). In natural settings, they are often surrounded by woodlands and have an inner, wetter zones featuring a variety of low shrubs, such as buttonbush and blueberry, as well as non-woody plants. Despite their isolated, seasonal nature, depressions provide critical habitat to many rare and threatened plants and animals and are especially vital to frog and salamander breeding.

Comparing Delaware's Natural Wetlands to Created Wetlands

Delaware's natural wetlands are strikingly dissimilar in appearance to created wetlands included in this report creating difficulties in identifying an HGM category to assess the wetland in. The created wetlands in this study ended up characterized as either flats or depressions using best professional judgement of the field crew, but the sites did not neatly fall into one category. The Island Farms site for example, was large, flat and level which mimicked the natural topography of a flat but held within the flat area were variable sized small depressions and upland mounds that were too small to be considered a wetland by themselves. In this instance, the consensus was to call the Island Farms site a flat.

In addition to the difficulty of assigning an HGM category, determining whether the designed unnatural topography of these created wetlands was inhibiting wetland function was also difficult to discern. Examples of these unnatural topographies included sites that: were surrounded by high berms or moats and contained odd small dug out pockets, high points, and ruts from heavy equipment. In a natural wetland assessment, these features would lower the wetlands score because they are considered to inhibit wetland function, but in the case of these created wetlands, they were intended to be there to create the wetland. As such, these types of features were not counted against the wetland sites.

As mentioned above, the hydrology in natural flat and depression wetlands has seasonal variations with dry periods in the summer and fall. The created wetland field sites were visited in the summer and still had water present with a mean average of 12.39 ± 13.59cm. The GIS study also noted a shift to wetter mapping signatures in their Cowardin classification, A, B & C's of impacted wetlands to E, F & H's of created wetlands. This leads to the question; will these wetlands survive climate change as sea levels rise and more frequent inundation from rains or storms occur?

Whether looking at wetland type, topography or hydrology of these created wetlands, a common theme became apparent: restored or created wetlands have not replicated the types of wetlands impacted or natural wetlands in Delaware. If or how this affects Delaware's flood water storage and water cleansing capabilities, or wildlife habitat at a watershed or landscape level remains undetermined.

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